REPORT

OF THE

EIGHTEENTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

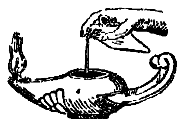
HELD AT SWANSEA IN AUGUST 1848.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1849.

PRINTED BY RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.



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OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other Institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

ADMISSION OF MEMBERS AND ASSOCIATES.

All Persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

COMPOSITIONS, SUBSCRIPTIONS, AND PRIVILEGES.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

Associates for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes :—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz. :—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845 a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members, who have intermitted their Annual Subscription in any subsequent year.

   Associates for the year. [Privilege confined to the volume for that year only.]

Subscriptions shall be received by the Treasurer or Secretaries.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons :—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.

2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.

3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.
4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.
5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the meeting of the year by the President and General Secretaries.
6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee, unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

I. Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.SS.L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
Sir T. MACDOUGAL BRISBANE, K.C.B., D.C.L., F.R.SS. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S., L. & E., &c. Sir John Robison, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chan. Univ. London. LIVERPOOL, September 11, 1837	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MOST NOBLE THE MARQUIS OF BREADALBANE. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. Wm. Keleher, Esq. Wm. Clear, Esq.

The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich. Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Bishop of Oxford, F.R.S. Prof. Owen, M.D., F.R.S. Prof. Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University. Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford The Very Rev. The Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Professor Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. Henry Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, Pres. Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G. S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Professor Willis, M.A., F.R.S.	Charles Tindale, Esq. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.

II. Table showing the Names of Members of the British Association who have served on the Council in former years.

Acland, Sir Thomas D., Bart., M.P., F.R.S.
Acland, H. W., B.M.
Adamson, J., F.L.S.
Adare, Viscount, M.P., F.R.S.
Airy, G.B., D.C.L., F.R.S., Astronomer Royal.
Ainslie, Rev. Gilbert, D.D., Master of Pembroke Hall, Cambridge.
Ansted, Professor D. T., M.A., F.R.S.
Arnott, Neil, M.D., F.R.S.
Ashburton, Lord, D.C.L.
Babbage, Charles, F.R.S.
Babington, C. C., F.L.S.
Baily, Francis, F.R.S.
Barker, George, F.R.S.
Bengough, George.
Bentham, George, F.L.S.
Bigge, Charles.
Blakiston, Peyton, M.D., F.R.S.
Brewster, Sir David, K.H., LL.D., F.R.S.
Breadalbane, The Marquis of, F.R.S.
Brisbane, Lieut.-General Sir Thomas M., Bart., K.C.B., G.C.H., D.C.L., F.R.S.
Brown, Robert, D.C.L., F.R.S.
Brunel, Sir M. I., F.R.S.
Buckland, Very Rev. William, D.D., Dean of Westminster, F.R.S.
Burlington, The Earl of, M.A., F.R.S., Chancellor of the University of London.
Bute, The Marquis of, K.T.
Carson, Rev. Joseph.
Cathcart, The Earl, K.C.B., F.R.S.E.
Chalmers, Rev. T., D.D., Professor of Divinity, Edinburgh.
Christie, Professor S. H., M.A., Sec. R.S.
Clare, Peter, F.R.A S.
Clark, Rev. Professor, M.D., F.R.S. (Cambridge).
Clark, Henry, M.D.
Clark, G. T.
Clerke, Major Shadwell, K.H., R.E., F.R.S.
Clift, William, F.R.S.
Colquhoun, J. C., M.P.
Conybeare, Very Rev. W. D, Dean of Llandaff, M.A., F.R.S.
Corrie, John, F.R.S.
Currie, William Wallace.
Dalton, John, D.C.L., F.R.S.
Daniell, Professor J. F., F.R S.
Dartmouth, The Earl of, D.C.L., F.R.S.
Daubeny, Professor Charles G. B., M.D., F.R.S.
De la Beche, Sir Henry T., F.R.S., Director-General of the Geological Survey of the United Kingdom.
Dillwyn, Lewis W., F.R.S.
Drinkwater, J. E.
Durham, The Bishop of, F.R.S
Egerton, Sir Philip de M. Grey, Bart., F.R.S.
Eliot, Lord, M.P.
Ellesmere, The Earl of, F.G.S.
Estcourt, T. G. B., D.C.L.
Faraday, Professor, D.C.L., F.R.S.
Fitzwilliam, The Earl, D.C.L., F.R.S.
Fleming, W., M.D.
Forbes, Charles.
Forbes, Professor Edward, F.R.S.
Forbes, Professor J. D., F.R.S.
Fox, Robert Were, F.R.S.
Gilbert, Davies, D.C.L., F.R.S.
Graham, Rev. John, D.D., Master of Christ's College, Cambridge.
Graham, Professor Thomas, M.A., F.R.S.
Gray, John E., F.R.S.
Gray, Jonathan.
Gray, William, jun., F.G.S.
Green, Professor Joseph Henry, F.R.S.
Greenough, G. B., F.R.S.
Grove, W. R., Esq., F.R.S.
Hallam, Henry, M.A., F.R.S.
Hamilton, W. J., M.P., Sec.G.S.
Hamilton, Sir William R., Astronomer Royal of Ireland, M.R.I.A.
Harcourt, Rev. William Vernon, M.A., F.R.S.
Hardwicke, The Earl of.
Harford, J. S., D.C.L., F.R.S.
Harris, Sir W. Snow, F.R.S.
Hatfeild, William, F.G.S.
Henslow, Rev. Professor, M.A., F.L.S.
Henry, W. C., M.D., F.R.S.
Herbert, Hon. and Very Rev. William, Dean of Manchester, LL.D., F.L.S.
Herschel, Sir John F.W., Bart., D.C.L., F.R.S.
Heywood, Sir Benjamin, Bart., F.R.S.
Heywood, James, M.P., F.R.S.
Hodgkin, Thomas, M.D.
Hodgkinson, Prof. Eaton, F.R.S.
Hodgson, Joseph, F.R.S.
Hooker, Sir William J., LL.D., F.R.S.
Hope, Rev. F. W., M.A., F.R.S.
Hopkins, William, M.A., F.R.S.
Horner, Leonard, F.R.S., F.G.S.
Hovenden, V. F., M.A.
Hutton, Robert, F.G.S.
Hutton, William, F.G.S.
Ibbetson, Capt., F.G.S.
Inglis, Sir Robert H., Bart., D.C.L., M.P., F.R.S.
Jameson, Professor R., F.R.S.
Jenyns, Rev. Leonard, F.L.S.
Jerrard, H. B.
Johnston, Professor J. F. W., M.A., F.R.S.
Keleher, William.
Lardner, Rev. Dr.
Lee, R., M.D., F.R.S.
Lansdowne, The Marquis of, D.C.L., F.R.S.
Latham, R.G., M.D., F.R.S.
Lefevre, Right Hon. Charles Shaw, Speaker of the House of Commons.
Lemon, Sir Charles, Bart., M.P., F.R.S.
Liddell, Andrew.
Lindley, Professor, Ph.D., F.R.S.
Listowel, The Earl of.
Lloyd, Rev. Bartholomew, D.D., Provost of Trinity College, Dublin.
Lloyd, Rev. Professor, D.D., F.R S.

Lubbock, Sir John W., Bart., M.A., F.R.S.
Luby, Rev. Thomas.
Lyell, Sir Charles, M.A., F.R.S.
MacCullagh, Professor, D.C.L., M.R.I.A.
Macfarlane, The Very Rev. Principal.
MacLeay, William Sharp, F.L.S.
MacNeill, Professor Sir John, F.R.S.
Meynell, Thomas, Jun., F.L.S.
Miller, Professor W. H., M.A., F.R.S.
Moillet, J. L.
Moggridge, Matthew.
Moody, T. H. C.
Moody, T. F.
Morley, The Earl of.
Morpeth, Viscount, F.G.S.
Moseley, Rev. Henry, M.A., F.R.S.
Mount Edgecumbe, The Earl of.
Murchison, Sir Roderick I., G.C.S., F.R.S.
Neill, Patrick, M.D., F.R.S.E.
Nicol, D., M.D.
Nicol, Rev. J. P., LL.D.
Northumberland, The Duke of, K.G., M.A., F.R.S.
Northampton, The Marquis of, V.P.R.S.
Norwich, The Bishop of, President of the Linnæan Society, F.R.S.
Ormerod, G. W., F.G.S.
Orpen, Thomas Herbert, M.D.
Owen, Professor Richard, M.D., F.R.S.
Oxford, The Bishop of, F.R.S., F.G.S.
Osler, Follett.
Palmerston, Viscount, G.C.B., M.P.
Peacock, Very Rev. George, D.D., Dean of Ely, V.P.R.S.
Pendarves, E., F.R.S.
Phillips, Professor John, F.R.S.
Porter, G. R., Esq.
Powell, Rev. Professor, M.A., F.R.S.
Prichard, J. C., M.D., F.R.S.
Ramsay, Professor W., M.A.
Rennie, George, V.P.&Treas.R.S.
Rennie, Sir John, F.R.S.
Richardson, Sir John, M.D., F.R.S.
Ritchie, Rev. Professor, LL.D., F.R.S.
Robinson, Rev. J., D.D.
Robinson, Rev. T. R., D.D., M.R.I.A.
Robison, Sir John, Sec.R.S.Edin.
Roche, James.
Roget, Peter Mark, M.D., F.R.S.
Ross, Capt. Sir James C., R.N., F.R.S.
Rosse, The Earl of, President of the Royal Society.
Royle, Professor John F., M.D., F.R.S.
Russell, James.
Sabine, Lieut.-Colonel Edward, R.A., For. Sec.R.S.
Sanders, William, F.G.S.
Sandon, Lord.
Scoresby, Rev. W., D.D., F.R.S.
Sedgwick, Rev. Professor, M.A., F.R.S.
Selby, Prideaux John, F.R.S.E.
Smith, Lieut.-Colonel C. Hamilton, F.R.S.
Staunton, Sir George T., Bart., M.P., D.C.L., F.R.S.
Stevelly, Professor John, LL.D.
Strang, John.
Strickland, H. E., F.G.S.
Sykes, Lieut.-Colonel W. H., F.R.S.
Symons, B.P., D.D., late Vice-Chancellor of the University of Oxford.
Talbot, W. H. Fox, M.A., F.R.S.
Tayler, Rev. J. J.
Taylor, John, F.R.S.
Taylor, Richard, jun., F.G.S.
Thompson, William, F.L.S.
Traill, J. S., M.D.
Turner, Edward, M.D., F.R.S.
Turner, Samuel, F.R.S., F.G.S.
Turner, Rev. W.
Vigors, N. A., D.C.L., F.L.S.
Vivian, J. H., M.P., F.R.S.
Walker, James, F.R.S.
Walker, J. N., F.G.S.
Walker, Rev. Robert, M.A., F.R.S.
Warburton, Henry, M.A., M.P., F.R.S.
Washington, Captain, R.N.
West, William, F.R.S.
Wheatstone, Professor, F.R.S.
Whewell, Rev. William, D.D., Master of Trinity College, Cambridge.
Williams, Professor Charles J.B., M.D., F.R.S.
Willis, Rev. Professor, M.A., F.R.S.
Winchester, The Marquis of.
Woollcombe, Henry, F.S.A.
Wortley, The Hon. John Stuart, B.A., M.P., F.R.S.
Yarrell, William, F.L.S.
Yarborough, The Earl of, D.C.L.
Yates, James, M.A., F.R.S.

THE GENERAL TREASURER'S ACCOUNT from 23rd of June

RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance brought on from last Account				169	15	2
To Life Compositions at Oxford and since				200	0	0
To Annual Subscriptions Ditto				207	0	0
To Associates' Subscriptions at Oxford				495	0	0
To Ladies' Tickets Ditto				203	0	0
To Book Compositions				2	0	0
To Dividends on Stock (£4500 three per cent. Consols) 18 mos.				196	12	0
To received from Sale of Publications:—						
Copies of the 1st volume	2	10	6			
2nd volume	3	5	8			
3rd volume	2	15	0			
4th volume	1	13	4			
5th volume	1	16	10			
6th volume	2	0	9			
7th volume	3	5	0			
8th volume	4	11	0			
9th volume	5	12	0			
10th volume	4	13	8			
11th volume	3	5	3			
12th volume	2	18	6			
13th volume	10	7	4			
14th volume	8	1	8			
15th volume	62	2	0			
16th volume	10	2	10			
Lithograph Signatures	0	12	0			
British Association's Catalogue of Stars	63	16	11			
Lalande's Catalogue of Stars	34	4	0			
Lacaille's Ditto	5	1	3			
				232	15	6
To Balance due to the General Treasurer	10	13	10			
Ditto Local Treasurers	3	9	5			
	14	3	3			
Less, Balance in Banker's hands	4	15	5			
Leaving Balance against the Account of				9	7	10
				£1715	10	6

G. R. PORTER,
JAMES HEYWOOD, } *Auditors.*

1847 (at Oxford) to 9th of August 1848 (at Swansea).

PAYMENTS.

	£	s.	d.	£	s.	d.
For Sundry Printing, Advertising, Expenses of Oxford Meeting, and Sundry Disbursements by Treasurer and Local Treasurers				448	1	1
Paid Balance of Printing, 15th Report (14th vol.)				81	1	7
Printing, &c. 16th Report (15th vol.)				508	6	2
Engraving, &c. for 17th Report (16th vol.)				28	0	0
Salaries to Assistant General Secretary and Accountant				375	0	0
Paid by order of Committees on Account of Grants for Scientific purposes, viz.—						
Researches on Atmospheric Waves	3	10	9			
Vitality of Seeds	9	15	0			
Completion of Catalogues of Stars	70	0	0			
Researches on Colouring Matters	5	0	0			
Acid on the Growth of Plants	15	0	0			
				103	5	9
Maintaining the Establishment at Kew Observatory:—						
Balance of Grant of 1846	42	11	6			
Part of Grant of 1847	129	4	5			
				171	15	11
				£1715	10	6

OFFICERS AND COUNCIL, 1848–49.

Trustees (permanent).—Sir Roderick Impey Murchison, G.C.St.S., F.R.S. John Taylor, Esq., F.R.S. The Very Reverend George Peacock, D.D., Dean of Ely, F.R.S.

President.—The Marquis of Northampton, V.P.R.S.

Vice-Presidents.—Viscount Adare. The Lord Bishop of St. David's. Sir H. T. De la Beche, F.R.S. The Very Rev. The Dean of Llandaff. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S.

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General Secretary.—Lieut.-Col. Sabine, For. Sec. R.S., Woolwich.

Assistant General Secretary.—John Phillips, Esq., F.R.S., York.

General Treasurer.—John Taylor, Esq., F.R.S., 2 Duke Street, Adelphi, London.

Secretaries for the Birmingham Meeting in 1849.—Charles Tindale, Esq. William Wills, Esq. Bell Fletcher, Esq., M.D. James T. Chance, Esq.

Treasurer for the Meeting at Birmingham.—James Russell, Esq.

Council.—Professor Ansted. Major Shadwell Clerke (deceased). Prof. E. Forbes. Prof. T. Graham. G. B. Greenough, Esq. W. J. Hamilton, Esq. James Heywood, Esq. Prof. E. Hodgkinson. Leonard Horner, Esq. Robert Hutton, Esq. Capt. Ibbetson. Sir R. H. Inglis, Bart. Dr. R. G. Latham. Sir Charles Lemon, Bart. Sir Charles Lyell. Sir C. Malcolm. Prof. Owen. G. R. Porter, Esq. Dr. Roget. J. Scott Russell, Esq. William Spence, Esq. H. E. Strickland, Esq. Lieut.-Col. Sykes. Rev. Professor Walker. The Dean of Westminster. Prof. Wheatstone. Rev. Dr. Whewell.

Local Treasurers. — W. Gray, Esq., York. Rev. E. Hill, Oxford. C. C. Babington, Esq., Cambridge. William Brand, Esq., Edinburgh. J. H. Orpen, LL.D., Dublin. William Sanders, Esq., Bristol. ———, Liverpool. ———, Newcastle-on-Tyne. James Russell, Esq., Birmingham. Professor Ramsay, Glasgow. ———, Plymouth. G. W. Ormerod, Esq., Manchester. William Clear, Esq., Cork. J. Sadleir Moody, Esq., Southampton. John Gwyn Jeffreys, Swansea.

Auditors.—Major Shadwell Clerke (deceased). James Heywood, Esq. G. R. Porter, Esq.

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Professor Agassiz, Neufchatel.
M. Arago, Paris.
Dr. A. D. Bache, Philadelphia.
Professor H. von Boguslawski, Breslau.
Monsieur Boutigny (d'Evreux), Paris.
Professor Braschmann, Moscow.
Chevalier Bunsen.
Charles Buonaparte, Prince of Canino.
M. De la Rive, Geneva.
Professor Dove, Berlin.
Professor Dumas, Paris.
Dr. J. Milne-Edwards of Paris.
Professor Ehrenberg, Berlin.
Dr. Eisenlohr, Carlsruhe.
Professor Encke, Berlin.
Dr. A. Erman, Berlin.
Professor Esmark, Christiania.
Professor Forchhammer, Copenhagen.
M. Frisiani, Milan.
Professor Henry, Princeton, United States.
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M. Jacobi, St. Petersburg.
Professor Jacobi, Königsberg.
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Professor von Middendorff, St. Petersburg.
Professor Nillson of Sweden.
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Chevalier Plana, Turin.
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Herr Plücker, Bonn.
Professor C. Ritter, Berlin.
Professor H. D. Rogers, Philadelphia.
Professor H. Rose, Berlin.
Professor Schumacher, Altona.
Baron Senftenberg, Bohemia.
Dr. Siljestrom, Stockholm.
M. Struvè of St. Petersburg.
Dr. Svanberg, Stockholm.
Dr. Van der Höven, Leyden.
Baron Sartorius von Waltershausen, Gotha.
Professor Wartmann, Lausanne.

Report of the Proceedings of the Council in 1847–48, presented to the General Committee at Swansea, Wednesday, August 9, 1848.

Report of the Council to the General Committee.

1. With reference to the subjects on which the Council was requested by the General Committee, assembled at Oxford, to make applications to Her Majesty's Government and to the Court of Directors of the East India Company, the Council has to report, that similar resolutions to those of the General Committee having been passed by the Council of the Royal Society, applications in accordance with them were made by the Presidents of that Society and of the British Association, acting conjointly, and were favourably received. On the subject of the first resolution, the Council understand from Lord Auckland's reply, that the Board of Admiralty will appropriate a suitable vessel for the purpose of an investigation into the Phænomena of the Tides, as soon as the most advisable plan for her employment shall have been determined upon, and proper instructions suggested. With respect to the second resolution, the Court of Directors of the East India Company have issued orders for carrying into regular and continued operation the tide observations on the coasts of Western India and Scinde;—and with respect to the third resolution, the Court of Directors have placed the standard bar and scale of the Indian arc of the meridian at the disposal of M. Struvè, and have permitted him to take it with him to Russia, in order that it may be there com-

pared with the similar instruments which have been employed in the measurements of the Russian arc of the meridian.

2. *The Council have been informed, that a deputation from the Philosophical Society of Birmingham has been appointed to present, at this Meeting, an invitation from that Society and from other public bodies at Birmingham, to the British Association, to hold the Meeting of 1849 in that town.*

3. The Council have received from Mr. Phillips, Assistant General Secretary, a communication entitled "Reasons for thinking that the Annual Meetings of the British Association ought not to be restricted to places which present formal invitations and guarantees of expenses." Considering the importance of the subject, and the respect due to the opinions of so experienced and zealous a friend of the Association, the Council have deemed it desirable that Mr. Phillips's communication should be brought to the notice of the General Committee on the occasion of presenting this Report: but having been apprised that an invitation is to be brought forward at Swansea to hold the Meeting of 1849 at Birmingham, and regarding this invitation as likely to be very favourably received, it has not appeared to the Council desirable to take any other present steps in reference to the subject of Mr. Phillips's communication, than that of bringing the communication itself to the notice of the General Committee. (See page xxi).

4. The Council have added the following names to the list of Corresponding Members of the British Association:—

M. Struvè of St. Petersburg.
M. Leverrier of Paris.
Charles Buonaparte, Prince of Canino.
The Chevalier Bunsen.
Professor Nillson of Sweden.
Professor Esmark of Christiania.
Dr. Van der Hoven of Leyden.
Dr. J. Milne-Edwards of Paris.

5. The Council have deemed it desirable to take into serious consideration the expediency of maintaining for a longer period the establishment at Kew; for this purpose they reappointed the Committee whose former report on the same subject was submitted to the General Committee at Southampton in 1846, and they now submit to the General Committee a second report from the same Committee. The Council have also to express their concurrence in the opinions contained in that report, with respect to the services which have been rendered to science by that institution, even on the limited scale on which alone it has been in the power of the British Association to maintain it; and to the probability that ere long the interests of science and the requirements of the public service will call for a Government establishment, having for its purpose some of the important objects originally contemplated by the observatory at Kew. The Council also concur in the opinion expressed by the Committee, of the expediency of deferring for the present a memorial to Her Majesty's Government on the subject.

Report of the Kew Observatory Committee.

The Committee appointed to consider the subject of the Kew Observatory having obtained from Mr. Ronalds a report on the actual state of the building, the instruments and other property of the Association therein deposited, as well as respecting the observations and experiments made there up to the present time, are enabled to state to the Council as respects the former, that

they are in a satisfactory condition, the building having undergone recently (on the representation by Mr. Ronalds to the Commissioners of Woods and Forests, in September 1847, of their necessity) such *external* repairs as suffice for its preservation, and that the instruments, such as are actually in use, are in good order and accomplishing the purposes of observation for which they have been constructed. An inventory of them has been furnished to the Committee by Mr. Ronalds, who is at present engaged in making out a complete catalogue of all the property of the Association on the premises.

In reporting on the scientific objects accomplished since their last report in 1846, they consider that they cannot do better than to extract such portions of Mr. Ronalds's reports above mentioned as bear upon this head.

"The journal of ordinary observations has proceeded as usual; fourteen observations per diem have been pretty constantly set down of electric observations.

"In the course of August 1846, many of the *magnetic* photographs were submitted to a rigid comparison with the corrected readings of the Greenwich magnet, and the result was officially declared to be 'highly satisfactory.'

"In the same month Dr. Banks brought an experimental specimen of his registering anemometer to Kew, and tried it at the north-eastern angle of the electric observatory.

"In September the third volume of Observations and Experiments was completed and carried to the Southampton Meeting of the British Association.

"In December 1846, having by experience (since the beginning of August 1845) found that my preliminary experiments, made upon a thermometer, a barometer, and an electrometer, each placed in the *same camera* or microscope *alternately*, fully warranted the cost of constructing apparatus of a durable and convenient character for each instrument, I began to make (at Chiswick) the photo-registering barometer, now at Kew, and spent several months in its completion. It is furnished with a compensating apparatus (on the principle of the gridiron-pendulum), whereby the necessity of a correction for temperature is certainly to a great extent, if not completely, avoided; it has one of Newman's standard tubes, and the image of the surface of the mercury itself is employed totally unencumbered by any ball, plug, float, or machinery of any kind; the mercury is therefore as free to act in this as in any standard barometer. And it can be at any time used without the compensating apparatus, if that should be deemed objectionable. The same time-piece moves this and the magnetic apparatus.

"In May 1847, the magnetic apparatus was improved by the substitution of new lenses by Ross in lieu of Voigtlander's. This enlarged the scale of declination.

"In January 1847, a complete electrical apparatus, exactly similar to mine in the dome at Kew for ordinary observations, was begun by Mr. Newman, by order of the East India Company, for the Bombay Observatory, and afterwards sent. Drawings were lent, instructions given, and electrometers made to correspond exactly with the Kew instruments.

"In November 1846, drawings relative to Mr. Scott Russell's experiments on the forms of vessels arrived at Kew, and I afterwards tried hard to get possession of the models themselves (in pursuance of a resolution of the Association), but without success.

"In May 1847, Mr. Hunt's actinometer arrived at Kew.

"In June 1847, the fourth volume of observations was completed and carried to the Oxford Meeting.

"At this meeting some conversation, &c. occurred about establishing an

electro-meteorological and magnetical observatory at Alten, in Finmark, and proposing to furnish some electrical apparatus from Kew and of my own, but nothing has been achieved in this way.

"In September 1847, repairs of the building becoming more urgent, I addressed a third application to the Woods and Forests through Mr. Phillips, and a new estimate for complete external and internal repairs was made, amounting to £271. The Commissioners, Mr. Milne, Mr. Burton, and Mr. Phillips, then visited the Observatory, examined it, and the apparatus, &c., and very soon afterwards all such repairs were executed as were fully sufficient to render it at least *wind-* and water-tight, which rendered a great service to the magnet.

"In November 1847, the magnetical apparatus was improved by the addition of a second condensing lens, placed beyond and very near to the index, and by an adjustment for the height of the lamp.

"At about the same time the barometric apparatus was improved by like means.

"In December 1847, the apparatus for registering photographically the electricity of the atmosphere now established at the south window of the south upper apartment (in pursuance of the experiments made in July and August 1845 *et seq.*) was in course of construction, and was completed in February 1848.

"I took much pains in the course of several months prior and subsequent to this time to arrange a system whereby photographic papers might be put into the microscopes (or camera) daily, and sent to Mr. Henneman's establishment, in Regent-street, to be there fixed and calotyped, and the positive impressions thence distributed to any meteorologists whom the British Association might think proper to appoint to receive them. These endeavours have been zealously promoted by Mr. Malone, and will become, I trust, useful.

"We now arrive at a circumstance which I (of course) cannot but esteem of importance. In Mr. Glaisher's remarks on the weather during the quarter ending December 31, 1847, for the Registrar-General's Report (at p. 2), he says, in reference to the Greenwich electrical apparatus,—'It is a fact well-worthy of notice, that from the beginning of this quarter till the 20th of December, the electricity of the atmosphere was almost always in a neutral state, so that no signs of electricity whatever were shown for several days together, by any of the electrical instruments,' &c. At this notice I sent to Greenwich an abstract from our journal of the maxima and minima of the two-hourly charges of the conductor during the same period, by which it was seen that the electricity of the atmosphere at Kew was *never* in a neutral state then, and I found that so low a charge was never observed during that time as has been observed in other periods. These circumstances were candidly stated in the next report. It was thought that this discrepancy between the two conductors, &c. might arise, wholly or in part, from the great length of the conducting wire, which extends from the top of the mast at Greenwich to the magnetic observatory, where the electrometers are placed. Both theory and experiment fully confirm my belief that this was the *chief* cause of the difference, and is the cause of a want of constancy in signs at Greenwich. (A few experiments upon my own conductor with a long wire have lately confirmed the fact still more.)"

On this report the Committee have to remark with satisfaction, as on scientific objects usefully and availably carried out,—1st. On the photogra-

phic self-registering processes which Mr. Ronalds has applied to the several objects of magnetic and meteorological observation—processes which (without reference to, or comparison with, what may have been doing simultaneously elsewhere or by others) appear to the Committee of much value and importance to the future progress of meteorological and magnetic inquiry; and, 2ndly, on the valuable series of electrical observations which have now been made during five years, and during the last three and a half at 2-hourly intervals day and night uninterruptedly, with observations also at sunrise and sunset. As these observations afford what it is presumed are not to be found at all, or at all events not for so long and consecutive a series, distinct numerical values of the electrical tension comparable at least *inter se*, the Committee have considered that they ought to undergo regular and complete reduction and discussion, with a view to eliciting from them the laws of the phænomena; and on this subject they have conferred with Mr. Birt, who has submitted to them a plan of reduction which they regard as satisfactory, and which he is willing to execute on a grant of £50 being made to him for that purpose; a sum which they consider not excessive, and which they strongly recommend the Council to propose to the general body at the ensuing meeting.

On the subject of the comparability of these results with those obtained, or to be hereafter obtained at Greenwich or elsewhere, it certainly would be desirable that some distinct series of comparative trials should be made; and the Committee would have considered the execution of such a series an important practical object to be accomplished during the next year of the continuance of the observatory, but for considerations which it is now their duty to state.

The question as to the expediency of continuing the present expenditure of the establishment has occupied the anxious attention of the Committee, conceiving that the Council, by making mention of it in their resolution of April 14, is desirous of having their opinion on this head. In endeavouring to form a sound one, they have taken into consideration the state of the funds of the Association, and also the circumstances of the establishment itself, which they are of opinion cannot for the future, or even for a single additional year, be carried on in a manner satisfactory to the Association *on so low a scale* of expenditure as that which, by a fortunate conjunction of personal circumstances eminently favourable, has hitherto been found practicable; and that in fact, to carry out fully some of the most important objects which have all along been contemplated in its occupation by the Association, a very considerable *increase* of outlay would, in their opinion, be annually necessary. Such increase however, in the actual state of the funds of the Body, they are by no means prepared to recommend—since they perceive that even the present expenditure (could they guarantee that it shall not be exceeded) must prove a drain upon those funds for which the amount of scientific advantage to be expected from it on a scale of action so limited, will not be held an adequate return. Entertaining this view of the matter, and conceiving it equally inexpedient either to attempt to raise by private subscription an annual amount adequate to the object, or to apply to Government for aid (although they consider it by no means impossible that ere long the exigences of the public service may require an establishment, having for its object some of the most important of those contemplated in this), they see no course open but to recommend its discontinuance from the earliest period at which it shall be found practicable, leaving it to the

Committee to ascertain (should the Council adopt this view) the most fitting mode of procedure for resigning it into the hands of Government, who have so liberally allowed the Association its temporary occupation.

Signed on the part of the Committee,
J. F. W. Herschel.

Reasons for thinking that the Annual Meetings of the British Association ought not to be restricted to places which present formal invitations and guarantees of expenses.

1. "By the rules of the Association, the General Committee has the duty of appointing the place, time and officers of the annual Meetings.

2. "By custom, this power has been limited to *places* which present invitations, to *times* suitable for those places, and to *officers* more or less indicated by local circumstances.

3. "The practice of obeying local invitations has been productive of good and evil: good by the spontaneous awakening of many important places to scientific activity; evil by the introduction of elements of display, temporary expedients, and unnecessary expense. These have somewhat impaired the efficiency of the Meetings, by withdrawing attention and consuming time which could ill be spared from the essential business of one scientific week.

4. "It is the opinion of the writer, that the balance of good and evil in this practice will become less and less favourable to the Association as time goes on; that by its operation the Meetings of the Association are likely to be made more dependent on commercial and other extrinsic considerations than on advantages of locality; that places in the highest degree desirable to be visited may not present invitations and guarantees; that invitations which it may be difficult to refuse may be pressed from places quite unsuitable for the Meeting; and that, finally, the Association may be reduced, not seldom, to the necessity of suspending its Meetings, or of seeing them poorly attended by unwilling members, unfruitful of knowledge and unproductive of money.

5. "He thinks the proper way to prevent these misfortunes is to declare that in making arrangements for the future Meetings, the General Committee will be guided by general considerations, and will regard as only one of the elements for its decision, the circumstance of special invitations from particular localities.

6. "And he thinks that this declaration should not be delayed beyond the Swansea Meeting, where we may speak from the vantage-ground of a very unanimous invitation from a place of singular attractions.

"He farther remarks that this plan will throw no discredit on invitations, which, as part of the elements for fixing on the places of Meeting, will still be acceptable and influential. Places presenting them, will still have the advantage, and often the preference, which such proof of scientific activity may deserve. The invitations will perhaps be as numerous after, as they have been before the change.

"There is no change necessary in respect of the previous arrangements, which must still include inspection of the localities, consultation with residents, &c. before the General Committee can be called on to decide.

"He will now say a few words on the financial part of this question.

"The system upon which the Association has been worked of late years, produces an expenditure of nearly £750 for the local expenses of rooms, printing, clerks and messengers, &c. at each Meeting. Of this £500 has been raised by local contributions, and the remainder paid by the British

Association. This expenditure is not all necessary. It arises in part from the system of accepting invitations and requiring guarantees. He estimates that £500 will be fully sufficient, if placed under his own management, to conduct a full meeting of the Association at a place previously selected. He even thinks £400 might be enough, if the sections be reduced to five (by uniting A and G), and care be taken in the appointment of clerks, messengers and printers.

"To provide for this expense, the Association must find the means of devoting £150 a year (at least) in addition to its present annual payments. But will this be all spent in vain? all lost? He thinks not. There is in the present system of raising *local funds*, a circumstance not to be overlooked which is productive of much loss to the Association. By raising so many hundred pounds at each place in the way of contribution to local expenses, there is really abstracted much from the contribution to the general purposes of the Association. Only a certain sum can be raised in the place, and the larger the contribution required for local objects, the fewer are the members, and the smaller the receipts of the Association. Gentlemen who might have paid £10, pay £2; those who might have paid £2, are content with paying £1; and in some cases the very demand of a local contribution has driven a member from the ranks of the Association.

"Again, by selecting for our place of meeting a central accessible point in an interesting district, where science has food and life, we may expect to secure a large local attendance of new members, and yet not lose our friends from a distance. But it has happened that a meeting by invitation has been so ill attended from public occurrences and peculiarities, as to cause a loss of many times £150 to the Association Treasury.

"Finally, as by this plan we do not preclude ourselves from the advantage of accepting invitations from the universities and large towns, but on the contrary can afford to wait for the years which may be most convenient to those places, there seems no objection of much strength to forbid the trial of it.

"In this case he would call attention to Derby, as centrally situated, very accessible, in a very interesting country which has not been visited, and by no means deficient in scientific activity. Derby affords abundant accommodation."

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE SWANSEA MEETING IN AUGUST 1849.

Involving Application to Government.

That the President and General Secretary be authorised to apply to Her Majesty's Government for the continuation of the Meteorological and Magnetical Observatory at Toronto, up to the 31st of December 1850.

Involving Grants of Money.

That Mr. Birt be requested to undertake the Reduction and Discussion of the Electrical Observations made at Kew, with the sum of £50 at his disposal for the purpose.

That the sum of £100 be placed at the disposal of the Council, for the expenses of Kew Observatory.

That Sir H. T. De la Beche, Sir William Hooker, Dr. Daubeny, Mr. Henfrey, and Mr. Hunt, be requested to investigate the action of Carbonic Acid on the growth of Plants allied to those of the Coal-formation, with the balance of the original grant (£5) at their disposal.

That Mr. Spence and Mr. T. V. Wollaston be a Committee for the purpose of assisting Mr. Newport in drawing up a Report on Scorpionidæ and Tracheary Arachnidæ, with the sum of £10 at their disposal.

That Professor E. Forbes and Professor T. Bell be a Committee for assisting Dr. T. Williams in drawing up a Report on the state of our knowledge of British Annelidæ, with £10 at their disposal.

That H. E. Strickland, Esq., Dr. Daubeny, Dr. Lindley, and Professor Henslow, be requested to form a Committee for conducting Experiments on the Vitality of Seeds, with £10 at their disposal.

That Professor E. Forbes, and the other members already named on the Committee for Dredging, with the addition of Colonel Portlock and Dr. Williams, be requested to continue their investigations, with £10 at their disposal.

That Dr. Lankester, Mr. R. Taylor, Mr. W. Thompson, Mr. Jenyns, Professor Henslow, Mr. A. Henfrey, Sir W. C. Trevelyan, Bart., and Mr. Peach, be requested to continue their superintendence of the drawing up of Tables for the Registration of Periodical Phænomena, with £5 at their disposal.

That certain Bills, amounting to £13 10*s*., on account of Anemometrical Observations, formerly carried on at Edinburgh, be paid; and that the Anemometer be transferred to the Assistant-General Secretary, at York.

Not involving Grants of Money, or Applications to Government.

That Dr. Schunck be requested to continue his Investigations on Colouring Matters.

That Dr. Andrews be requested to prepare a Report on the Heat developed in Chemical Action.

That Mr. R. Hunt be requested to prepare a Report on the present state of our Knowledge of the Chemical Influence of the Solar Radiations.

That Professor E. Forbes, Dr. Playfair, Dr. Carpenter, and M. A. Hancock, be a Committee to report on the Perforating Apparatus of Mollusca.

That Mr. Mallet be requested to continue his preparation for a Report on the Facts of Earthquakes.

That Mr. G. G. Stokes be requested to prepare a Report on Physical Optics, in continuation of Dr. Lloyd's Report on that subject.

That the communication of Dr. Percy on the Extraction of Silver by the wet way, be printed entire in the next Volume of Transactions.

That the Communication by Mr. Joseph Glynn, on Hydraulic Pressure Engines, be printed entire in the next Volume of Transactions.

That a Communication by Mr. J. P. Budd, on the advantageous Use made of the Gaseous Escape from the Blast Furnaces of Ystalyfera, be printed entire in the Transactions.

That the Assistant General Secretary be authorised, on consultation with Professor Powell, to insert in the next Volume of Transactions, such portions of Professor Powell's Communication on Luminous Meteors, as may be necessary to complete the recorded observations of that Phænomenon.

That the Committee appointed in 1838, for determining the resistance of Railway Trains, be re-appointed, for the purposes of repeating those experiments at the high velocities, and in the altered circumstances of Railways at the present time,—the following Gentlemen to form the Committee, viz.: —Mr. Hardman Earle, Mr. George Rennie, Mr. Edward Woods, Mr. T. Froude, Mr. J. Glynn, Mr. Wyndham Harding, and Mr. J. S. Russell.

That the Assistant General Secretary be requested to form a complete List

of all the Recommendations that have been made by the Association, accompanied by a Report of the manner and extent to which these recommendations have been carried into effect; to be printed and placed in the hands of the Committees of Sections.

In consequence of the Report which the General Committee has received from the Council on the subject of the Kew Observatory, the General Committee concur with the Council in regretting that the means at the disposal of the British Association are insufficient to carry out on the extended scale which would be required for that purpose, the important objects which were contemplated by the Institution at Kew; they also concur in the expediency of discontinuing the endeavour to accomplish their objects with means which are confessedly inadequate.

The General Committee has granted the sum recommended to be employed in the reduction and discussion of the important and unique series of Electrical Observations which have been made at Kew under the superintendence of Mr. Ronalds, and they further remit to the care and conduct of the Council the steps which are necessary to be taken for the discontinuance of the Kew Observatory.

The General Secretary having suggested the expediency of inserting in the Rules of the British Association a paragraph to the effect that those Gentlemen who have held the office of President of the Association, should be *ex-officio* members of the Council,—

The General Committee request that the Council will take this suggestion into their consideration, and report their opinion thereon to the General Committee at its first Meeting in Birmingham.

Synopsis of Grants of Money appropriated to Scientific Objects by the General Committee at the Swansea Meeting in August 1848, with the Name of the Member, who alone or as the First of a Committee, is entitled to draw for the Money.

	£	s.	d.
Kew Observatory.			
At the disposal of the Council for defraying Expenses........	100	0	0
Mathematical and Physical Science.			
Bills incurred for Anemometrical Observations at Edinburgh..	13	10	0
BIRT, W. R.—Discussion of Electrical Observations	50	0	0
Geology.			
DE LA BECHE, Sir H. T.—Influence of Carbonic Acid on Vegetation	5	0	0
Natural History.			
STRICKLAND, H. E.—Vitality of Seeds....................	10	0	0
LANKESTER, Dr.—Periodical Phænomena of Animals and Vegetables	5	0	0
SPENCE, W.—Report on Scorpionidæ and Arachnidæ........	10	0	0
FORBES, Prof. E.—Dredging Committee	10	0	0
FORBES, Prof. E.—Report on British Annelidæ	10	0	0
Total of Grants........£213	10	0	

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions......	284	1	0
Chemical Constants ..	24	13	6
Lunar Nutation	70	0	0
Observations on Waves.	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature .	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments....	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions......	29	0	0
British Fossil Fishes ..	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (strength of) .	60	0	0
Animal and Vegetable Substances (preservation of)	19	1	10
Carried forward	£308	1	10
Brought forward	308	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee ..	50	0	0
Heart Experiments....	5	3	0
Land and Sea Level ..	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth ..	63	10	0
Mechanism of Waves ..	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature .	21	11	0
Vitrification Experiments	9	4	7
Cast Iron Experiments .	100	0	0
Railway Constants	28	7	2
Land and Sea Level ..	274	1	4
Steam-Vessels' Engines.	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air......	16	1	0
Cast and Wrought Iron.	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie..	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics......	50	0	0
	£1595	11	0

1840.	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phænomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céléste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Carried forward	£539	10	8
Brought forward	539	10	8
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (British Association Catalogue of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Carried forward	£1442	8	8

	£.	s.	d.
Brought forward	1442	8	8
Questions on Human Race	7	9	0
	£1449	17	8
1843.			
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Carried forward	£977	6	7

	£.	s.	d.
Brought forward	977	6	7
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Observations on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2
1844.			
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars .. 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Carried forward	£384	2	4

	£	s.	d.
Brought forward	384	2	4
Influence of light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes, 1842	23	11	10
Researches into the Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas.......1842	100	0	0
Geographical distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds..1842	8	7	3
Researches on Exotic Anoplura	15	0	0
Experiments on the Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument, 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Carried forward	£399	10	1

	£	s.	d.
Brought forward	399	10	
Meteorological Instruments at Edinburgh	18	11	
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
Experiments on the Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura..1843	10	0	0
Vitality of Seeds..1843	2	0	7
Vitality of Seeds..1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Registration of Earthquake Shocks..1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars, 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1839	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Experiments on the Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds..1844	2	15	10
Vitality of Seeds..1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Carried forward	£605	15	10

	£	s.	d.
Brought forward	605	15	10
Marine Zoology of Britain	10	0	0
Exotic Anoplura..1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs .	2	3	6
Researches on Atmospheric Waves	3	3	3
Captive Balloons..1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality at York ..	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1839	50	0	0
Carried forward	£50	0	0
Brought forward	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall..............	10	0	0
Researches on Atmospheric Waves......	6	9	3
Vitality of Seeds......	4	7	7
	£100	16	10

1848.

	£	s.	d.
Researches on Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters .	5	0	0
On Growth of Plants ..	15	0	0
	£103	5	9

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money for scientific purposes have been entrusted, are required to present to each following meeting of the Association a Report of the progress which has been made; with a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Association expire at the ensuing meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

In each Committee, the Member first named is the person entitled to call on the Treasurer, John Taylor, Esq., 2 Duke Street, Adelphi, London, for such portion of the sum granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the Members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named shall be deemed to include, as a part of the amount, the specified balance which may remain unpaid on the former grant for the same object.

General Meetings (in the General Meeting-Room, Park Street).

On Wednesday, August 9th, at 8 P.M., the late President, Sir Robert Harry Inglis, Bart., F.R.S., M.P. for the University of Oxford, resigned his Office to the Most Noble the Marquis of Northampton, President of the Royal Society, who took the Chair at the General Meeting, and delivered an Address, for which see p. xxxi.

On Thursday, August 10th, at 8 P.M., John Percy, Esq., M.D., F.R.S., delivered a Discourse on the Metallurgical Operations of Swansea and its neighbourhood.

On Monday, August 14th, at 8 P.M., William Carpenter, Esq., M.D., F.R.S., delivered a Discourse on Recent Microscopical Discoveries.

On Wednesday, August 16th, at 3 P.M., the concluding General Meeting of the Association was held, when the Proceedings of the General Committee, and the grants of money for scientific purposes were explained to the Members.

The Meeting was then adjourned to Birmingham in September 1849*.

* The Meeting is appointed to commence on Wednesday, the 12th of September, 1849.

ADDRESS

BY

The Most Noble the Marquis of NORTHAMPTON,

Pres. R.S., F.S.A., Hon. M.R.I.A., F.L.S., F.G.S.

Gentlemen,—In addressing you on the present occasion, I cannot but feel the disadvantageous situation in which I am placed as compared to my friend Sir Robert Inglis, who has just yielded to me the honourable situation of your President.

I am not, as he was last year, addressing you in an ancient and venerable seat of academic discipline, where the very aspect of the surrounding buildings proclaimed the long residence of learned leisure and elegant taste;—where, during the lapse of very many centuries, science and learning have made their abode, and where religion has consecrated their union. There, in that Oxford which has sent forth so many labourers for the cultivation of knowledge,—where the divine, the statesman and the philosopher have taken their early lessons in those arts which were to make their names household words among their countrymen—there, where the Royal Society had its cradle, the British Association might well anticipate a generous welcome, and more than that, an audience fit though not few, and not only favour but assistance in its pursuits;—assistance from a Daubeny, a Powell, a Buckland and others who were among its earliest supporters and members. In going, indeed, to Oxford the Association did not go to fresh fields and pastures new. Its visit was no experiment, for it had already gone to the friendly banks of the Isis, and found there a kind and warm reception when it was itself but young; when it had not already received the marked patronage of the British public, and when favour and kindness were the more valuable.

The British Association has now arrived at a part of our Sovereign's dominions where it cannot enjoy similar advantages. Remote from the metropolis,

*remote from the chief seats of English learning, remote also from those great highways of communication by which modern ingenuity has almost accom*plished the extravagant wish of annihilating space and time, Swansea cannot with reason expect a meeting numerous as those of York, and Cambridge, and Oxford, and still less like those that have congregated at Liverpool and Glasgow. Deprived, however, of the advantages to which I have alluded, Swansea still possesses some attractions, and can advance some special reasons why, sooner or later, it would be the duty of the British Association to select it for its place of meeting. Among these, I should select as one of the most important a consideration which is in some sense an objection; namely, the fact that its inhabitants are in a corner, as it were, of Great Britain—that they are separated from the highways of steam. It is one of the objects of the British Association to visit all parts of Great Britain;—to carry the torch of science everywhere, not only to enlighten but to receive fresh light from every portion of the island. Had Swansea been as accessible from Bristol as Bath is, a visit to Bristol might have sufficed for Swansea also, just as a visit to Southampton may be considered a visit to Portsmouth also.

Unless, however, the Association had come to Swansea itself, South Wales would have remained unvisited, and a large geographical portion of the island would have been left unknown to the Association in its corporate capacity.

Again, Wales comprehends an important and separate portion of the island; a people to whom at one time the whole of it belonged—a people speaking a different and more ancient language, civilized when the Saxon and Norman ancestors of the proud London, and Oxford, and Cambridge of modern times were heathens and barbarians—a people who had seen among them a Julius Cæsar and a Constantine. These considerations will be of great interest at least to the Ethnological Section of the Association.

To the mineralogist and geologist, again, the mineral riches of Wales, to which England is so much indebted for its manufacturing prosperity and political importance, will be no small attraction. Moreover, the chemist and mechanician will be anxious to witness the ingenious processes by which iron and copper are here, on a gigantic scale, separated from their ores. These reasons are amply sufficient to account for, and indeed to demand, a visit from the Association,—without mentioning the warm invitation that we have received, the kind hospitality that we have been promised. To those members of the Association who were at Southampton and Oxford it would be quite superfluous to allude to the eloquent terms in which the advocate of Swansea, Prof. Grove, like a potent magician, or like a representative of the

Bard and Druid of ancient Britain, summoned us to the shores of the Bristol Channel.

When I acknowledge, however, that there are abundant reasons why the Association should sooner or later visit Swansea, I have not therefore said that that visit ought to have taken place this year. On the contrary, there is one reason why it would have been better had it been postponed to a later period. In that case it would probably have had a more efficient President than myself. Wholly unconnected as I am with this place, I cannot think that I should have been called on to preside had I not still continued to hold the high and honourable office in the Royal Society which I am about in a few months to resign.

Indeed my present position in the Royal Society is the only reason that could justify me in accepting the invitation,—and I must candidly say that I think it sufficient. I can conceive nothing more important to both societies, in some of their chief functions, than a close union of feeling, and when occasion calls for it a union of action also. Thus their influence is enabled to bear with greater weight on the Government of their own country,—and in one instance at least, it has done so, through their own, on the Governments of other countries also.

It has been the habit of my predecessors in this chair, on occasions similar to the present one, to advocate the claims of the British Association on the goodwill of their countrymen, and to state the services that it has performed to the cause of knowledge. They have pointed not only to the papers read and discussions held in our different Sections, but also to the Reports drawn up with the greatest care by men of the highest abilities and eminence during our vacation. They have indicated the important scientific investigations and experiments carried on at our request and at our expense, and which would not have so soon, if at all, been carried on had the British Association not existed. They have summoned as witnesses in favour of the Association the band of illustrious foreigners who have joined our ranks, and, making themselves Englishmen for the time, have given us the honour of their presence, the assistance of their science and the pleasure of their friendship. Finally, my predecessors have been able proudly to advert to the services performed by our Government at the request of the Association, backed on several occasions by the Royal Society. They have had it in their power, for instance, to advert to the reduction of catalogues of stars, to the cession of the Royal Observatory at Kew, to the expedition of Sir James Ross, and to the great combination for inquiries on terrestrial magnetism. This has been the sort of argument, overwhelming as it seems to me, that my predecessors were at first called to adopt. I cannot think that more than this slight allu-

sion is required from me. The British Association has now existed eighteen years;—it has visited the chief universities and the most important commercial towns of the empire, with the exception of London, which is excluded by our provincial character;—it has everywhere received the most kind, the most generous encouragement:—it may therefore well consider itself as established in public favour, and requiring neither justification nor defence.

My friend Sir Robert Inglis, in his admirable address at Oxford, gave you an elaborate account of the discoveries of the year in most of the branches of knowledge,—including much indeed that could hardly, in strictness, belong to such narrow limits. I shall not endeavour to follow his example. Indeed, I do not think that it is at all necessary that such a course should be an annual one, however advisable from time to time. I think it would be a fatigue to you were I to pursue it. Besides this, I know my own physical strength would not be equal to so long an address, and that were I to attempt it I should incapacitate myself for the performance of my duties for the rest of the week. There are, however, some points to which I think it right to allude.

First, then, I will refer to the great system of inquiring into terrestrial magnetism now carrying on by our own and other Governments, at the united request of the British Association and the Royal Society. I am rejoiced to be able to say, that in spite of the politically disturbed state of the continent of Europe, those inquiries have not been suspended,—and I hope they will be continued to the period which was proposed for them by the Magnetic Congress at Cambridge. It was then proposed that they should be brought to a close at the end of next December. I trust, however, that the valuable inventions by which at Greenwich and at Kew magnetical disturbances are noted by self-registering instruments will secure still more ample information than we shall have already attained at the termination of the present year.

The next subject to which I must advert, is the Observatory at Kew,—and I do so with a mixture of pleasure and of pain. I have said pleasure and pain. I advert to it with pleasure on account of the important scientific observations that have been there made,—the detail of which will, probably, be laid before you. I advert to it with pain, as the expenses of keeping it up have been so great that it will not be within the power of the Association to continue to do so much longer.

Among the contents of our last volume I think it right to refer to what may be considered in a great degree a novel feature,—the ethnological portions that occupy a very considerable space. The names of their authors will be a sufficient guarantee of their value. Among these we find one who

represented the Government as well as the deep learning of his country—a gentleman who, having commenced his literary career by aiding a Niebuhr, and having since brought before the world a laborious work on the mighty sovereigns of ancient Egypt, has now come among us with a valuable essay on the general philosophy of language. I will not occupy your time by further allusion to these ethnological communications,—but I think it proper, in addressing you from the chair, to add a word of caution. It is one of the most important and essential rules of the British Association that party politics and polemics be entirely excluded from our proceedings. It is, however, vain to deny, unless their authors are put on their guard, that there is danger that these forbidden topics may steal into ethnological papers. There is also another danger, namely, that they may become too historical or too literary. Against similar risks my predecessors have felt themselves called on to warn the Statistical Section, and I hope I may be excused for following their example, when there is a similar danger.

It must be very gratifying to geologists to see a mathematician so eminent as Mr. Hopkins apply a mind accustomed to the severest studies to the most important and difficult subjects of geology,—as we have seen in his report and his papers on the theories of earthquakes. The question itself is one of the greatest difficulty,—one that has exercised the talents and divided the opinions of the ablest philosophers,—one that requires for its solution the aid of many sciences. It is therefore one particularly fitted to be presented to a meeting like this where men of every science are present. In itself, this may be considered as giving a direct and sufficient answer to those who ask what is the use of the British Association.

At our meeting at Southampton, Sir John Herschel, in words of singular poetic beauty, first intimated, as I believe, to an English audience, the remarkable astronomical discovery which so soon after was announced to the whole world, and which added an unknown planet to our system. I had the honour, as President of the Royal Society, to give to M. Leverrier the medal awarded to him by our Council,—my predecessor in the chair had the satisfaction of receiving at Oxford both Leverrier and Adams—the two gentlemen who had simultaneously, though without concert, pursued the same original and laborious investigation in search of the great celestial globe that disturbed the course of Uranus. Of the two discoverers of Neptune, I fear that I cannot hope to see here the illustrious countryman of Laplace; Mr. Adams perhaps may honour Swansea with a visit. Certain I am that you, Gentlemen, would delight to welcome the two philosophers whose names will now shine together like a twin star so long as astronomy shall be considered the sublimest of sciences.

In our last volume is a communication of a highly interesting and instructive nature on the microscopic structure of shells, by Dr. Carpenter, for the illustration of which by numerous excellent plates the Association has gone to a considerable expense. I believe this to be a most judicious expenditure. The subject is one of the highest interest, not only in itself, and as affording the means of identifying fragments of shells in rocks where they are rare, but also in connexion with the analogous inquiries of Prof. Owen into the structure of teeth. The microscope seems every day to rise into increased importance as a scientific instrument, affording the physiologist the same means of penetrating into the depths of organization that the telescope gives the astronomer to pierce into the depths of space. I am sure you will be glad to know that a public body, the Trustees of the British Museum, have paid Dr. Carpenter the compliment of appointing him to a lectureship founded in the most liberal manner by the late Dr. Swiney. I believe, Gentlemen, you will yourselves have the pleasure of hearing him give an oral exposition of his investigations.

I am sure, Gentlemen, that the members of the British Association must have derived the liveliest satisfaction from what I may call one of the principal events in science that has occurred since our last meeting;—I mean the publication by Sir John Herschel of the results of his arduous labours at the Cape of Good Hope. We cannot indeed associate our body in any way with that great scientific enterprise. It was undertaken at no suggestion from us or from any other scientific society. Its author was influenced alone by his own love of science and by the desire to complete the labour of his illustrious father; and I believe that in truth the son had more to do with it than the philosopher,—and science will be proud that it was so. Though, however, we cannot derive any glory to the British Association from Sir John Herschel's brilliant success in the Southern Hemisphere, we may still be proud of him as one of our earliest members,—as one to whom we bade adieu on the banks of the Cam at our third meeting, then welcomed again at our fifteenth as our President. Welcome, indeed, his presence must be on whatever occasion he may come amongst us!

Although the British Association did not take any active part in the recommendation of the Expedition sent out by the Government under Sir John Franklin, and have therefore not the same immediate interest in its success that they had in Sir James Ross's Expedition into the South Polar region, yet I am sure that we must all feel the most anxious desire for the safety of our gallant countrymen. I wish it was in my power to give you any satisfactory information on this point. Alas! I cannot do so. I can do no more than express the hope that the same gracious Providence which shielded Sir

James Ross amid the Antarctic icebergs may stretch out its arm and bring back again our brave navigators.

Europe, Gentlemen, has now seen a general peace established with only partial interruption for the long and unaccustomed period of thirty-three years. Happily, science has made its way while the sun of prosperity has shone,—for the prosperity of science depends much more on peace and order than on favour and patronage. Favour and patronage have, however, not been wanting. It is fortunate that the followers of science have so done, for times have arrived when it would be idle to expect similar progress. It may be flattering and honourable to literature and science to see a great nation choose her rulers among her poets and astronomers, but to poetry and astronomy it is undoubtedly an evil. Who can regret the compelled retirement from public life that enabled Milton to write his great, his divine poems? Who can rejoice that a very different ambition should have taken Newton from the studies that gave the world his 'Principia'? Who can tell how much his Mastership of the Mint may have retarded the advancement of science? There cannot be a doubt that many a master mind will now be led away from pursuits the most congenial to it by the absorbing and prompting demands of political necessity. Still less can it be doubted that the industrious ants of science who laboriously bring to her granaries their numerous though small additions,—who, in truth, accumulate facts destined for materials for the greater minds that reason and systematise,—these industrious labourers, I say, will be employed in very different ways. The something new which will be sought by them will be political and not scientific: the balloting box will be more attractive than the crucible,—the sword of the partisan than the hammer of the geologist. These considerations induce me to fear that we have no right to expect our Meeting will this year be honoured by the presence of many of our friends from abroad, even if the distance of this locality did not interpose material difficulties in their way.

It is not, however, for the sake of accounting for the absence of illustrious foreigners that I have made these remarks. It is rather for the purpose of observing, that happily philosophers of this country have no such excuse for idleness or remissness in carrying on their usual scientific labours. On the contrary, they have the stronger reason for doing so. They ought to remember that while England is exempt from the unhappy disturbances of other countries, the sacred flame of science is especially confided to them by the same gracious Providence that protects their happiness, their freedom, their sovereign, their laws, their independence.

Like our soldiers and our sailors, like the ministers of the laws of the land and the expounders of the laws of morality and religion, the inquirers into

those other laws which regulate His creation,—the searchers out of the means by which the knowledge of His laws may benefit his creatures,—have duties to perform which it is criminal in them to neglect: doubly criminal, if to them it be given in an especial degree to perform those duties by a special exemption from the evils which oppress their fellows elsewhere.

In England, these duties devolve, in particular branches of knowledge, on particular societies; but in science in general, and in all its ramifications, they rest in a more especial manner on the Royal Society and on that which now I have the honour of addressing. To the former I have nothing to say in this place. To the latter it is my present duty to address myself. To you, then, Gentlemen, I say heartily, that it would not become you to rest on your oars, or to look at the goodly volumes that contain your Reports and record your proceedings, and to say, "We have done enough." You have not done enough. You are bound by the engagement you have taken in becoming members of this noble body—you are bound to Sir David Brewster, its originator—to Mr. Harcourt, its legislator—to Lord Fitzwilliam, who took the honourable but perilous post of its first President, and to those officers who have so zealously served it, to do your best for its continued prosperity. Now, Gentlemen, in considering how this object is to be attained, we must look not only to what it has achieved and to its present popularity, but also to the other side of the question, if there be another side. I am sorry to say there is another side.

You are all, or most of you, aware, that for many years our pecuniary funds were increasing, and that we made large grants of money for scientific purposes. You must also be aware from whence those funds arose; namely, from the annual and life subscriptions of our members. Our annual subscriptions are now of a very limited amount; being almost entirely confined to those members who join us in different localities, many of whom only pay in a subscription for one year. It is true that we have funded a portion of our life-subscriptions; but a considerable part of them has been applied to scientific grants,—more perhaps than we were strictly justified in so applying. The consequence has been, that for several years our expenditure has exceeded our income. It would be vain to dissemble, and idle to deny, the inevitable consequence of such a continued excess. There is only one method, without deviating from our accustomed mode of action, by which we can remedy this serious evil. It is one, fortunately, that is consistent with our prosperity in other respects. We must return to some of those great seats of population and industry where we have a fair prospect of a large temporary accession to our members, and through them of a large addition to our funds. I am happy to say that we have reason to anticipate an invitation from at least one such place for the ensuing year.

However this may be, Gentlemen, I cannot but believe that, were it necessary or considered advisable, an appeal to the generosity of those friends of the Association who have followed its progress from year to year would not be made in vain.

I cannot conclude this address without expressing the gratitude of the Association for the great liberality that has been exhibited by the Corporation and inhabitants of Swansea for our reception. It has, on this occasion, been shown in many ways of a most unusual nature for the convenience of the scientific guests that are here expected. I know that all this must have been done at a very heavy expense, clearly proving that the inhabitants of South Wales duly appreciate the importance of scientific pursuits. One of our Vice-Presidents, Mr. Dillwyn, whose eminence in the pursuit of natural history has been a great inducement for our visit to Swansea, has greeted our arrival with an important volume on the Fauna and Flora of the neighbourhood, of which he has kindly placed a considerable number of copies to be used for the advantage of gentlemen most interested in botany and physiology. The edifice in which I address you is consecrated to religion; thereby intimating the belief that science, when followed in a right spirit, is a pursuit not unworthy of those who are believers in the World's Book as well as inquirers after the material works of the Almighty;—intimating also the hope that the British Association will ever seek after knowledge in a Christian spirit of kindness and humility, for the benefit of man and the glory of God.



REPORTS

ON

THE STATE OF SCIENCE.

A Catalogue of Observations of Luminous Meteors. By the Rev. BADEN POWELL, *M.A., F.R.S. &c., Savilian Professor of Geometry, Oxford.*

(A communication ordered to be printed among the Reports to the Association.)

IN the Volume of Reports of the British Association for 1847 I have given a very imperfect list of observed luminous meteors, as far as I could collect them, for the several years subsequent to the termination of M. Quetelet's very complete catalogue (Nouv. Mem. Acad. Bruxelles, tom. xi.). With a view to enlarging and carrying on this design from year to year, I have been desirous to form at least the nucleus of a collection of all observations of this kind under the auspices of the British Association; and my wishes have been responded to by numerous correspondents, from whose valuable communications, as well as the data furnished by several journals, I have been enabled to draw up the annexed catalogue; which includes a few observations of earlier years, but is more full for the later; reaching down to the present time. It is now offered to the British Association as presenting a condensed view of existing observations collected in one record: the original documents, as communicated to the author, are collected in the Appendix, and references are made to the sources of information in other cases. To any such catalogue doubtless many additions may remain to be made; and it is hoped that such contributions will be forwarded to the author at Oxford, who will embody them in a continuation of the catalogue at a future time.

TABLE OF LUMINOUS METEORS.

Date.	Description.	Place.	Observer.	Reference.
1833.				
Sept. 17	Four meteors, with an aurora	York	Prof. Phillips	Lowe's Atmospheric Phenomena, 174.
1838.				
Mar. 17	A large meteor	Kensington	Idem.	Ibid. 233.
1841.				
Mar. 22	Several; small	Durham	Prof. Chevallier	Ibid.
Aug. 10.	Several; some brilliant	Plymouth	Prof. Phillips	MS.
1842.				
Aug. 9	Numerous. 80 in 3 hours, with an aurora.	Gosport	H. Maverly, Esq.	Ibid. 156.
Aug. 9	24 in an hour (one observer)	Malvern	Prof. Phillips*	
Oct. 4	A remarkable meteor	Cambridge	Mr. J. Glaisher.	Lowe's Atmospheric Phenomena, 367.

* Bulletin de l'Acad. Roy. Appendix, No. 70.

Date.	Description.	Place.	Observer.	Reference.
1843.				
Aug. 9	Many meteors	Cork	Prof. Phillips	MS.
13	Many meteors	Nottingham	Mr. Lowe	Appendix, No. 6.
Oct. 16	Many; one large	Ibid.	Id.	Ibid. No. 7.
Nov. 10–12	A small white mass, dispersed with an explosion in day-time; clear sky.	Austria	Mr. G. T. Vigne	Ibid. No. 1.
Nov. 18	A brilliant meteor	Nottingham	Mr. Lowe	Ibid. No. 8.
1844.				
Jan. 26	Many	Ibid.	Id.	Ibid. No. 9.
Aug. 8, 9	Many	Dryburn	Mr. Wharton	Ibid. No. 2.
10	Very numerous and bright	Durham	Id.	Ibid.
Oct. 18	Many	Nottingham	Mr. Lowe	Ibid. No. 10.
Nov. 11	One; brilliant	Ibid.	Id.	Ibid.
12	Many; very brilliant	Birmingham	Mr. Onion	Atmos. Phen. 351; Appendix, No. 11.
13	Four; large	Nottingham	Mr. Lowe	Appendix, No. 12.
1845.				
Jan. 31	Several; large	Ibid.	Id.	Ibid. No. 13.
Feb. 5	Several	Ibid.	Id.	Ibid. No. 14.
April 24	One; large and brilliant	Ibid.	Id.	Ibid. No. 19.
24	The same. Form not defined; no explosion.	Greenwich	Sir J. Herschel	Atmos. Phen. 230.
June 18	Luminous appearances at sea, and in Syria.		A Correspondent	Appendix, No. 3.
July 16	One; large	Belgium		Bulletin, R. Acad. Brussels, 352.
29	Very near Earth	Nottingham	Mr. Lowe	Appendix, No. 20.
Aug. 10	100 in one hour	Paris?	M. Coulvier Gravier.	L'Institut, 288.
10	Great numbers in Cassiopeia, Cygnus, &c.	Dijon	M. Perrey	Ibid. 211.
10	One; large	London	Many Observers	Journals.
10	Cloudy; but light of meteor seen.	Oxford	Prof. Powell	Proc. of Ashmolean Society, No. 22.
Sept. 7	0h 22m; one; large and bright; changed colour; coruscations; another, smaller.	London, Regent's-park.	Mr. Hind	Atmos. Phen. 231.
	A valuable and detailed table of observed places by stars, &c. Some of the most remarkable are—	Bombay	Prof. Orlebar, M.A.	Observations at the Meteor. and Magn. Observatory, Bombay, 4to, 1845, p. 170.
Oct. 28–30	Several; one large			
31	Many; nine in six hours			
Nov. 2–7	One or two each night			
4, 6, 14	Large ones			
Dec. 9	10h 15m; remarkable; bright; and six smaller.			
3	One meteor, with an aurora; light of meteor increased when crossing the aurora.	Nottingham	Mr. Lowe	Atmos. Phen. 127; Appendix, No. 15.
3	One; large	Mentz	A Correspondent	Appendix, No. 15.
1846.				
Feb. 10	9 P.M.; large and brilliant	Caraman	M. de Roquette	Comptes Rendus, 1846, i. 739.
11	One; large	Nottingham	Mr. Lowe	Appendix, Nos. 32, 33.
12	Ditto. Motion horizontal	Ibid.	Id.	Ibid.
21	9h 6m P.M. Two large globular meteors near together.	Collioure	M. Berge and others.	Comptes Rendus, 1846, i. 739.

Date.	Description.	Place.	Observer.	Reference.
1846.				
Mar. 21	$6^h 45^m$ P.M.; one; large. Discussed by M. Pettit, and inferred to be a satellite to the Earth.	Toulouse	M. Pettit, &c. ...	Comptes Rendus, 1846, i. 739; ii. 704.
22	Meteor fell and set fire to a building.	Bagnères	Id.	Ibid. 739.
22	Several..........................	Nottingham...	Mr. Lowe	Appendix, No. 31.
May 29	One; bright; ascending from horizon to zenith.	Ibid............	Id.	Ibid. No. 21.
30	A few	Ibid............	Id.	Ibid. No. 36.
June 3	Light and explosion; others reported a large meteor.	Moreton Bay, Australia.	Mr. M'Connell...	Ibid. No. 5.
July 23	$9^h 30^m$ P.M.; one; large. M. Pettit calculates path, and concludes it to be a satellite to ⊖.	Toulouse ...	MM. Bianchi, Voisins, &c.	Comptes Rendus, 1847, ii. 259.
	Others	Cazeres ...		
25–30 ...	Many	Nottingham...	Mr. Lowe.........	Appendix, Nos. 16, 17.
Aug. 10	(Cloudy at Oxford).			
9–13 ...	Number of meteors in ¼ hour, observed at several times on each night, varying from 1 to 6 in ¼ hour.	Dijon	M. Perrey	Comptes Rendus, 1847, ii. 478.
14	Ten from $9^h 15^m$ to $10^h 15^m$ ...	Ibid	Id.	Ibid.
21	One; very brilliant.............	St. Apre	M. Moreau	Ibid. 549.
25	One; brilliant...................	Nottingham...	Mr. Lowe	Appendix, No. 38.
26	Ditto	Ibid	Id.	Ibid. No. 39.
Sept. 5	A few	Ibid	Id.	Ibid. Nos. 40, 41.
10	One, with an aurora; light increased in crossing aurora.	Nottingham...	Id.	Ibid. No. 18.
13	One; brilliant...................	Paris	Dr. Forster	Comptes Rendus, 1846, ii. 550.
25	10 P.M. Large; moving N. from zenith; train curved, and serpentine afterwards.	London	Correspondent to Mr. Lowe.	Atmos. Phen. 233; Appendix, No. 22.
25	Same observed	Nottingham, Wiltshire, Warwickshire.	Many Observers..	Journals.
25	Same. Illumination over sky; zigzag train; no explosion.	Cambridge ...	Rev. J. Ventris...	Ibid.
25	Similar appearance	Farnborough, Kent.	Sir J. Lubbock...	Phil. Mag. xxx. 4.
25	Ditto	Rosehill, Oxford.	Rev. J. Slatter...	Ibid. xxxi. 368, and Appendix, No. 4.
Oct. 9	One; large; $9^h 15^m$ P.M.	Paris	M. Cadart	Comptes Rendus, 1846, ii. 718.
9	The same.........................	St. Germains & other places.	M. Chasles, M. Grutey.	Ibid. 814. 834.
10	One; large; $8^h 45^m$ P.M. Ditto 8 P.M.	Ferté sous Jouerre.	M. Rigault	Ibid.
16	Several; motion horizontal ...	Nottingham...	Mr. Lowe	Appendix, No. 42.
17	$6^h 15^m$ P.M. Two; brilliant; in one the train collapsed.	Dijon	M. Perrey	Comptes Rendus, 1846, ii. 985.
17	One brilliant meteor, with coruscations, &c.	Ramsgate, London, Wales.	Many Observers	Journals.
Nov. 9	$7^h 30^m$ P.M.; large	Dijon	M. Melline	Comptes Rendus, [1846, ii. 986
9	$8^h 5^m$ P.M.; a luminous globe...	Ibid............	M. Geoffroy......	Ibid.
18	Several..........................	Nottingham...	Mr. Lowe.........	Appendix, No. 43.
19	One; brilliant...................	Avranches, Dijon.	M. Jelinski, M. Perrey.	Comptes Rendus, Ibid.
Dec. 21	Many; one large	Nottingham...	Mr. Lowe	Appendix, No. 44.

Date.	Description.	Place.	Observer.	Reference.
1847.				
Jan. 11, 15	Many	Nottingham	Mr. Lowe	App., Nos. 23, 24.
Feb. 11	One; brilliant	Versailles		Comptes Rendus, 1847, i. 307.
Mar. 17	Several; two remarkable	Nottingham	Mr. Lowe	Appendix, No. 25.
May 31	Several; large	Ibid	Id.	Ibid. No. 26.
June 21	Ditto. Some with an aurora (light increased in crossing aurora).	Ibid	Id.	Ibid. No. 27.
Aug. 7	One; brilliant	Paris	M. Desdouits	Comptes Rendus, 1847, i. 765.
9	Several; large	Nottingham	Mr. Lowe	Appendix, No. 28.
10	Numerous; thirty or forty in half an hour; S.W.	Dryburn	Mr. Wharton	Appendix, No. 58.
10	Fifteen from $9^h 55^m$ to $10^h 25^m$, and at intervals till $11^h 30^m$ about as many; often two and three together; S.W.	Oxford	Prof. Powell	Proceedings of Ashmolean Society, 1847, No. 8.
17	One; brilliant	Luxembourg	M. Desdouits	Comptes Rendus, 1847, ii. 508.
19	$9^h 18^m$ P.M. several. Discussions and calculations by Le Verrier and others.	Dieppe	M. Nell de Bréauté.	Ibid. 316 and 461.
Oct. 11	Two meteors	Bruges	Dr. Forster	Appendix, No. 59.
18	$10^h 30^m$ P.M.; one; brilliant	Paris	M. Laisnè	Comptes Rendus, ib. 629.
Nov. 1	Numerous; some large	Nottingham	Mr. Lowe	Appendix, No. 29.
12, 13	Several	Dryburn	Mr. Wharton	Appendix, No. 60.
12, 13	Numerous	Benares	Correspondent to M. Arago.	Comptes Rendus, 1848, i. 7.
12, 13	Several; large	Nottingham	Mr. Lowe	Appendix, No. 30.
17	One; large	Nottingham	Id.	Ibid. No. 31.
19	$4^h 30^m$ A.M. One; very remarkable; large; slow motion; *twice stationary* in descending from zenith to horizon, therefore course probably serpentine.	Near Oxford	Mr. Symonds	Ibid. No. 62.
19	One; large; $7^h 51^m$ P.M.	Paris	M. Laugier	Comptes Rendus, 1847, ii. 733.
Dec. 12	Many	Nottingham	Mr. Lowe	Appendix, No. 45.
1848.				
Jan. 4	Several	Nottingham	Id.	Ibid. No. 46.
Feb. 7	One; brilliant	Ibid	Id.	Ibid. No. 47.
20	Several, with an aurora (light increased in crossing aurora).	Ibid	Id.	Ibid. No. 48.
Mar. 9	A luminous appearance; passed off and disappeared without exploding.	Near Oxford	Mr. Symonds	Ibid. No. 63.
April 1	Several; some brilliant	Nottingham	Mr. Lowe	Ibid. No. 49.
6	One seen in daylight, $7^h 5^m$ P.M.	Oxford	Mr. Symonds	Ibid. No. 64.
23	Numerous from 10^h to 12^h P.M.	On the Clyde	Id.	Ibid. No. 65.
28, 29, 30	Several	Nottingham	Mr. Lowe	Ibid. Nos. 50, 51, 52.
30	One; brilliant; train separated into two parts.	London, Regent's-park.	Mr. F. Barnard	Ibid. No. 66.
May 2, 3, 5, 7	Several	Nottingham	Mr. Lowe	Ibid. 53–56.
11	A train of light descending vertically.	Wootton, near Oxford.	Mr. P. Duncan	Ibid. No. 67.
23	One; small	Nottingham	Mr. Lowe	Ibid. No. 57.
July 12	One; large; slow; with a train.	Nottingham	Id.	Ibid. No. 68.
29	10 P.M; bright with train and sparks.	Bradfield, Berks.	Rev. C. Marriott.	Ibid. No. 69.

APPENDIX.

Details referred to in the Catalogue, from the original Records of Observations of luminous Meteors, communicated to Professor Powell by the Authors.

No. 1. Extract from a letter from G. T. Vigne, Esq. to Prof Powell.

"About the 10th or 12th of November 1843, I was descending the Danube.... near what is said to be the bridge of Severus..... about 5 P.M. ......I heard a loud report like that of a musket; the day was clear without a cloud; I saw a perfectly white cloud or mist, evidently the result of the explosion, slowly dispersing in no particular shape, in three or four minutes. I should say it was about a mile or a mile and a half above the earth, and distant about four. No part of it seemed to descend; it dispersed as it were from a stationary nucleus. When I first saw it, the white cloud might be about as large as the end of your finger held up at about twelve or eighteen inches from the eye."

2. See Durham Advertiser, August 16th, 1844. No moon; clear atmosphere. Many meteors on the 8th; more on the 9th; very numerous and brilliant on the 10th. Nearly all in parallel directions from N.E. to S.W. Many in trains, apparently at great elevations. 11th, 12th, 13th cloudy; 14th clear, but no meteors.

3. Extract from the Malta Mail, see 'Times,' August 18th, 1845.

June 18th, at $9^h 30^m$ P.M., brig Victoria, in lat. 36° 40′; long. 13° 44′ E.; in a sudden calm after wind. "An overpowering heat and stench of sulphur. At this moment three luminous bodies issued from the sea, about half a mile from the vessel, and remained visible ten minutes."

At Ainab on Mount Lebanon, on the same day, half an hour after sunset, was seen "a meteor composed of two luminous bodies, each apparently five times as large as the moon, with streamers or appendages from each joining the two; in the west; remained visible for an hour, taking an easterly course, and gradually disappeared."

Both accounts sent by a correspondent to Prof. Powell, but it does not appear whether the latter is from the same source as the former; or on what original authority either rests.

4. Extract from a letter to Prof. Powell from the Rev. J. Slatter, of Rosehill, near Oxford.

"I saw it [the meteor of Sept. 25th, 1846] at the height of about 50°; it seemed to move along a meridian line, and rather to decline in height as it moved northerly, but not more than might be the effect of perspective if it moved parallel to the earth; it passed over the zenith of London. Taking the longitude of the place of observation as $4^m 55^s$ W., the value of 1^s=6·155 mile, the distance due west of the meridian of London=about 45·65 miles, and the height of the meteor from the earth is 54·4 miles.

"It appeared less than half the diameter of the sun; which would give a diameter of 500 or 600 yards. At a rough guess its velocity might be 25 miles in a second."

5. Mr. David C. M'Connell, in a letter to Prof. Powell, mentions that on the 3rd of June 1846, at 8 P.M., at Moreton Bay, on the Brisbane River, South Australia, about 27° S. lat. and 152° 30′ E. long., being within doors, he saw a light and heard an explosion like that of a cannon at a distance in a still clear night. Many natives stated that they had seen a bright body like the moon passing from east to west. It is also added that it passed at an altitude of about 75° to the south, and the explosion was heard when the meteor was about 30° from the western horizon.

It was also ascertained that 10 miles west from the place nothing was heard; 10 miles S.W. the meteor was seen and the explosion heard; as it was also to 25 miles S.E.

Extract of a letter from E. J. Lowe, Esq. to the author:—

"My dear Sir,—There is one circumstance in connexion with falling stars that I could never understand, which is this: when a falling star crosses an auroral beam or arch it instantly brightens; this I have not only noticed on one day, but on four or five different ones when this phænomenon has taken place during a display of aurora; indeed on every display since the period when I first noticed them brighten, the same has again occurred. This is a fact worthy of further notice. It appears to me that the falling stars and aurora borealis must be at the same elevation above our earth, and if so, we shall then be better enabled to calculate the height of aurora. I am inclined to imagine that an aurora has never yet been accurately measured, for to do so we must suppose the arch a single one, and it is probable that we each observe under different circumstances.—EDWARD JOSEPH LOWE."

To this was appended the following:—

Meteors copied from 'Treatise on Atmospheric Phænomena' seen by the Author.

6. 1843. August 13th. From 8^h to 9^h many falling stars, especially near Cassiopeia, Cygnus, and Ursa Major.

7. 1843. October 16th. From 6^h to 8^h many caudate meteors crossed the sky; one of more than ordinary dimensions passed from the constellation Pegasus through Cygnus, Lyra and Corona Borealis, and faded away in Bootes near Arcturus, leaving a brilliant stream of light behind it for a few seconds.

8. 1843. November 18th, $11^h 20^m$. Observed a beautiful caudate meteor; first noticed it near Sirius; it passed through δ Orionis, Bellatrix, Aldebaran, Hyades, Pleiades, β and γ Arietis, between α and β Andromedæ, and faded away near β Pegasi. Its disc appeared as nearly as possible about three times the size of the apparent disc of the planet Jupiter.

9. 1844. January 26, $11^h 45^m$. Many falling stars, especially near Orion, Gemini and Canis Minor.

10. 1844. October 18th. Many falling stars, chiefly near Cetus, Aries and Ursa Minor.

11. 1844. November 11th, 7^h. A falling star; fell from β Andromedæ to α Ceti.

12. 1844. November 13th, 9^h. Saw four large meteors. The first fell from β Cassiopeia to η Tauri; second, from η to β Tauri; third, from Capella to γ Tauri; and the fourth from Pegasus to η Tauri.

13. 1845. January 31st, $12^h 14^m$. A large caudate meteor of a red colour traversed the interval between Cor Leonis and Procyon, leaving a brilliant light behind it for about a second after its disappearance. At $12^h 37^m$ a meteor passed from Cor Caroli to Arcturus. At $12^h 44^m$ a beautiful blue meteor fell from the Pole-star to a little north of Cassiopeia. $12^h 54^m$ another red meteor passed about 6° east of η Ursa Majoris.

14. 1845. February 5th, 5^h. Several falling stars.

15. 1845. December 3rd, $8^h 23^m$. A small meteor fell from the constellation Cygnus, through a very brilliant auroral arch (see Atm. Phen. p. 127), at α Pegasi, which left a trail of light behind it for the space of a second;

the light when it crossed the auroral arch became instantly more brilliant, and remained visible longer in the arch than in any other portion of its track; it vanished about 5° beyond the auroral arch. Many other falling stars were visible during the evening, but no other crossed the arch.

On this day a large meteor of a globular form burst over the town of Mentz at a height of only 150 feet from the earth. It gave out a brilliant light, followed by an immense quantity of black smoke. (From the Athenæum or Lit. Gazette.)

16. 1846. July 25th. All night many falling stars.

17. 1846. July 30th. At night many falling stars, especially in the Great Bear. $9^h 3^m$. One of the most brilliant of them fell through the two stars to the north of the Pointers, *i.e.* λ and ν Draconis.

18. 1846. September 10th, $9^h 45^m$. A falling star passed through an auroral arch at α Andromedæ; it instantly brightened as it crossed the phænomenon. The case of suddenly brightening occurred twice more, viz. at $9^h 54^m$, when a falling star crossed the arch at α Pegasi; and at $9^h 56^m 40^s$, when another meteor passed through the phænomenon, also at α Pegasi. Several falling stars were also noticed in Ursa Major. I conceived that the falling stars moved with greater rapidity this evening than I had noticed them do before. The falling stars were of a pale blue colour, of small size, and had luminous tails.

19. 1845. April 24th, $9^h 32^m$. Noticed a small falling star in Ursa Major. At $9^h 35^m$, the night, which was very dark, suddenly became light as day, and the objects, near and distant, were visible as plainly as in broad daylight; immediately a magnificent meteor of a blue colour was seen traversing the interval from the zenith to 30° S. by E. of it (the zenith). Its apparent size was very nearly equal to that of the moon's disc, and perfectly round in form, but its brilliancy far surpassed that luminary; its intensity of light could not possibly have been less than three times that of our satellite. No train of light was left behind it, and the meteor, after moving 30° in the direction of S. by E., which it accomplished in less than three seconds, exploded near φ Leonis Majoris, and moved in small fragments of light for the space of 1°, and then became suddenly extinguished. It appeared of no considerable height in the air. The meteor passed through the stars 21, 30, 40 and 41 Leonis Minoris; 95, 96, χ, 59, π, and 75 Leonis Majoris. (This meteor was seen in Greenwich Park by Sir John Herschel, who calculated its height to have been 90 miles; see Atmos. Phæn. p. 230.)

20. 1845. July 29, $8^h 16^m$. A meteor resembling a large spark from a candle was seen in a N., slightly W. direction; it was extremely bright, but not larger in appearance than the Pole-star. This meteor appeared to be very little elevated above our earth. I have never before noticed one which appeared so low down in the atmosphere. I should say a hundred yards was the greatest height it could be; it had not the appearance that meteors generally have, but resembled a spark drawn from an electrical machine.

21. 1846. May 29th, $11^h 5^m$. A brilliant caudate meteor of a red colour fell from the star ζ Ophiuchi, through 23, σ and α Ophiuchi, through o Herculis, and faded away near α Lyræ. The course was one in which these meteors are not often observed to travel, being from the direction of the horizon into the zenith.

22. 1846. September 25th. A very grand meteor at about ten o'clock; when first noticed at Nottingham it was about 20° E. of the zenith, and fell in a S.E. direction. I regret I did not see this fine meteor.

Meteors not hitherto recorded, except a few of them, in Meteorological Reports.

23. 1847, January 11th. Many falling stars.

24. January 15th, 12^h. Several falling stars.

25. March 17th, 8^h 30^m. Several falling stars; at this hour two fell; the first from Rigel, the second from α Orionis through ϵ Orionis.

26. May 31st. From 10^h several large caudate meteors.

27. June 21st, 11^h 30^m. Tolerable-sized meteor fell from 7° south of α Canium Venaticorum to γ Cephei. 11^h 50^m. Another from δ Ursæ Majoris through γ Ursæ Majoris. 11^h 51^m. Small one through Coma Berenices. 11^h 57^m. One through Dubhe, and another through γ Ursæ Majoris, and another through the Pole-star; all three within 30″. On this occasion several of these stars fell through an auroral arch visible at the time, and when doing so they invariably brightened, and appeared to linger in the arch; probably the fact of being instantly more brilliant would make them appear to the eye lingering.

28. August 9th. Several large caudate meteors. 9^h. One from α Lyræ to Adrisded.

29. November 1st. All evening many small stars, and about 8^h several caudate ones in and near Lyra. 7^h 59^m. Blue meteor from α Lyræ to γ Cygni. 7^h 59^m 30^s. From δ Lyræ to Atair. 8^h 11^m. From β Cygni through Delphinus.

30. November 13th. Several large falling stars. 10^h. One through Draco and Hercules.

31. November 17th, 9^h 3^m. Caudate meteor from Lyra to Aquila.

32. 1846, February 11th, 10^h 30^m. A large straw-coloured meteor fell from the zenith through Capella and the Pleiades.

33. February 12th, 10^h 3^m. A star shot across the sky at an altitude of 30° for upwards of 30° parallel with the horizon, leaving a trail of light of nearly 10° behind it as it progressed; it commenced in the Great Bear and went easterly; several others of small size were noticed.

34. March 22nd. Few small falling stars.

35. May 29th, 10^h. A falling star fell from Serpentarius, and disappeared near ϵ Lyræ.

36. May 30th. Few falling stars.

37. July 29th. Many falling stars.

38. August 25th, 9^h 17^m. A large meteor of a straw-colour fell in N.W. When first seen it was passing through Cor Caroli, and it faded away in Leo Major, near the star θ. It was about four times the size of the disc of Jupiter, and was very brilliant, and left a trail of light behind it. It faded away very suddenly.

39. August 26th, 10^h. A meteor fell from η Ursæ Majoris, and disappeared 5° below Cor Caroli; the stream of light left behind lingered some time before disappearing.

40. September 5th. A few falling stars.

41. September 20th. Some falling stars.

42. October 16th. Several falling stars shot parallel with the horizon.

43. November 18th, 7^h. Several falling stars.

44. December 21st. Many falling stars; some of them of a tolerable size: they were mostly in Orion, Canis Major, Canis Minor, and Taurus. One at 9^h, larger than the rest, passed through the Pleiades and ϵ Orionis.

45. 1847, December 12th. Many falling stars noticed in the constellations Orion, Taurus, Gemini and Auriga. At 7^h 50^m, one three times the appa-

rent size of Jupiter, with a blue tail, fell slowly from the star β Tauri through Bellatrix.

46. 1848, January 4th, 6^h. P.M. Several small falling stars.

47. February 7th, 11^h. A brilliant meteor of a red colour, and about twice the apparent size of Jupiter, fell from about 2° below that planet.

48. February 20th, 11^h 40^m. Several falling stars were noticed in Ursa Minor. At 11^h 47^m one fell from about 5° above Alderamin, and when it crossed a ray of aurora (which passed through this star at the time) it instantly brightened. The phænomenon of suddenly becoming bright when crossing auroral beams I have noticed in several former displays, and especially when crossing the magnificent auroral arch of 1845, December 3rd. This is a fact worthy of particular notice.

49. April 1st, 11^h 18^m. A brilliant blue meteor fell from Jupiter between Castor and Pollux. 11^h 19^m 30^s. A smaller one fell from Jupiter through Cor Caroli; several others were noticed.

50. April 28th, 10^h 15^m. Small falling star fell from the two stars ε and ζ Aquilæ to Atair, and moved rather slowly; at 11^h 50^m another small star went on the same track.

51. April 29th, 9^h 45^m. Meteor from Draco through Rastaban. 9^h 55^m. Small meteor through the Polar star. 10^h 10^m. Small falling star through Draco from α Draconis.

52. April 30th, 11^h 10^m. Falling star fell through Rastaban.

53. May 2nd, 11^h 49^m. A small falling star fell from ν Cygni.

54. May 3rd, 11^h 30^m. Several falling stars noticed, of small size, principally in Caroli. At 11^h one larger than the rest fell from Cor Caroli.

55. May 5th, 11^h 23^m. Small falling star fell from γ Lyræ through β Cygni to α Delphini.

56. May 7th, 10^h. Falling star from γ Lyræ to ε Aquilæ. 10^h 40^m. Falling star from β Cephei through β Cassiopeiæ.

57. May 23rd, 12^h 3^m. Small star fell from α Cygni to 80 (π 1) Cygni; this moved rapidly and soon disappeared; no trail of light.

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58. See Durham Advertiser, August 15th, 1847.

Time of observation, 11 to 11½ P.M. Number 30 to 40; generally ranging E.N.E. or N.E. to W.S.W. or S.W., having luminous streaks.

59. From the Bruges Journal, October 11th, 1847, communicated by Dr. Forster.

"Cette nuit, à 7 minutes avant 2 heures, M. Forster étant encore à ses observations astronomiques, a vu un météore jaunâtre qui prit naissance à 2° 30′ S.S.O. de la planète Mars et se dirigeant vers le O.N.O. jusqu'à l'horizon, et laissant après lui une longue trainée de lumière; 1′ 40″ après il vit un autre météore tout près de l'horizon se dirigeant vers la même direction, mais ayant pris naissance au midi, il était d'une clarté bleuâtre."

60, 61. See Durham Advertiser, November 19th, 1847.

November 12th and 13th, nights partly cloudy, yet at intervals clear. Several meteors between 6 and 7 P.M. on the 12th, but very few afterwards or on the 13th; mostly from E. to W. One bright like a star of first magnitude at 6^h 5^m across Pisces. Motion slow with a train from E. to W.

62. The following is the substance of Mr. Symonds' verbal statements to Professor Powell.

1847. November 19th. 4½ A.M. he saw a remarkable meteor of large apparent diameter, passing slowly down from about the zenith, where it was first observed, towards the S.W.

At about 45° elevation it became *stationary*, and remained so for seven minutes, Mr. S. observing the time by his watch, for which there was sufficient light. It then continued its descent till about 20° elevation, when it became *stationary again* for a like time. It then descended till lost to view by the intervening trees, &c.

63. 1848. March 9th, $1^h\ 45^m$ A.M. Cloudy. Mr. Symonds, at Wytham Park, near Oxford, saw a slight luminosity in the atmosphere apparently between the observer and the clouds. It moved horizontally from E. to W., and as it advanced enlarged and assumed the appearance of a curved band, with its convexity towards the west, towards which it moved parallel to itself till it acquired a luminous head at the lower part, and then disappeared: the whole lasted 22 seconds.

64. 1848. April 6th, $7^h\ 5^m$ P.M. The same gentleman saw near Oxford a bright meteor shoot across the zenith from N. to S., though it was then daylight.

65. 1848. April 23rd, from 10^h to 12^h P.M. The same observer, passing down the Clyde in a steamer, saw an unusual number of meteors.

66. From a letter to Professor Powell from F. Barnard, Esq., dated 8 Cross-street, Islington, May 1st, 1848.

At $7^h\ 30^m$ P.M., April 30, the writer, in company with a friend in Regent's Park, saw a meteor descend from the zenith about half-way to the horizon, when his friend saw it separate into two parts and disappear; to himself it seemed to disappear simply. It lasted two or three seconds; direction nearly S.W. It was still daylight. There had been a remarkable yellow fog in the morning. Its size appeared, "about that of a Roman-candle ball."

67. P. B. Duncan, Esq., late Fellow of New College, Oxford, in a note to Professor Powell, observes that the peculiarity of the appearance which he witnessed, May 10th, at half-past ten, near Wootton (Woodstock), was a luminous stream descending *vertically*. He had seen many inclined or horizontal.

68. Extract from a letter from E. J. Lowe, Esq. to Professor Powell.

"I hasten to inform you of the large meteor seen here last night (July 12th, $7^h\ 15^m$ P.M.) which crossed beneath the moon. The meteor was very nearly, if not quite, a fourth the size of the moon, and when first seen was 5° to the south of that luminary; and at an altitude above the horizon, when first seen, of about 5° less than that of the moon. It moved in an angle with the S.W. horizon of about 45° towards the west horizon. This meteor was remarkable on account of the slowness with which it travelled; it must have occupied from 3″ to 4″ in moving about 20°. Its colour was an intense blue, and the meteor left a trail of light which gave only from the blue mass pale-red sparks of large size; some larger than first magnitude stars. The meteor was of a peculiar shape, being that of a cone; unfortunately a tree prevented my viewing its disappearance; the tree was only 10° in diameter, therefore must have vanished within 10°. It required three minutes to get a full view of the spot where it must have vanished, and then all traces of the phænomenon had disappeared. The meteor appeared to cross near or over the only star visible below the moon and to the west of it; this star I took to be *a* Libra, from its position and size.

"At $11^h\ 47^m$ a meteor of the size of a second magnitude star moved from Corona Borealis to Benetnasch; it was of a blue colour, and moved exceedingly rapid. Others were noticed during the night; I did not see them."

69. Extract from a letter to Prof. Powell from the Rev. C. Marriott, Fellow of Oriel College, dated Bradfield, Berks, July 29th, 1848.

"Within half a mile of this place, about ten to-night, I saw a shooting-star as bright as Venus, and drawing a bright train as if of sparks or globules, I

could not say which, they vanished so rapidly. It appeared a few degrees below the Pole-star, or a little to the eastward, and descending towards the western horizon, *hit* the lowest of the Pointers, and disappeared a few degrees beyond it."

70. In this communication (to M. Quetelet) the author remarks that the "Zenithal line parallel to which the greatest number of meteors were directed, was from N.N.E. to S.S.W. nearly as observed in the previous year, [at Plymouth]. Others passed to the northward, and on combining the whole it resulted as a general view, that the movements appeared to originate about a point N.E. of the zenith, near Cassiopeia, and that the meteors passing southward were more numerous than those proceeding to the north."—Bull. de l'Ac. Roy. de Bruxelles, 1842, p. 324–326.

On Water-pressure Engines.

By JOSEPH GLYNN, *F.R.S., M. Inst. C.E. &c.*

(A communication ordered to be printed entire among the Reports to the Association.)

AT the last meeting of the British Association in Oxford, I read a report on the Turbine as a means of obtaining mechanical power, with a rotary motion from falls of water in circumstances where a water-wheel could not be employed. The report I propose to submit to the present meeting relates to another mode of employing the power of waterfalls, in a manner essentially different, but not less useful and important, which appears to have been too much neglected in this country, considering the advantages to be derived from it in hilly districts for the drainage of mines. The paper on the Turbine is printed in the last volume of the Transactions; the present paper, which may be regarded as another branch of the same subject, describes the application of high falls of water to produce a reciprocating motion by means of the pressure-engine, as has before been done with respect to the production of a rotary motion by means of the Turbine.

The first invention of the water-pressure engine, like many other mechanical contrivances, appears to belong to Germany, and most probably had its origin in Hungary, where so many ingenious machines actuated by water have long been used. In the pressure-engine the power is obtained from a descending column of water acting by its weight or hydrostatic pressure upon the piston of a cylinder, to give motion to pumps for raising water to a different level, or to produce a reciprocating motion for other purposes.

In mountainous districts, so often containing great mineral wealth, waterfalls may be found of a much greater height than can be practically brought to bear upon water-wheels; and the stream is often too small in quantity to produce the desired effect on a water-wheel within the ordinary limits of diameter. In such situations the pressure-engine is well-adapted to derive great mechanical power from a fall of water for working pumps and machinery for draining mines.

The Germans appear to have made successive improvements upon their original engines, and to have extended, from time to time, their usefulness and application, of which two important examples may be given.

The one is at Illsang in Bavaria, at the salt-works, which are situated in the southern part of the kingdom. These works are supplied from a mine of rock-salt in the valley of Bergtesgaden and from the salt springs at Reichenhall, where the salt was formerly purified by solution and evaporation; but as this operation could not be carried on with advantage on account of the scarcity of fuel, the saturated brine is now conveyed by a line of pipes seven inches in diameter, through which it is forced from stage to stage for a

distance of about sixty miles by a series of nine pressure-engines, acted upon by falls of water from the hills, and each of them working a pump.

A description of these engines will be found in the Proceedings of the Institution of Civil Engineers, and an excellent drawing, by Mr. W. L. Baker, of one of the best engines of the series, constructed by M. de Reichenbach, will be found in the collection of that institution. This engine has a cylinder of twenty-six inches in diameter, with a stroke of four feet, making in regular work five strokes per minute; it is made entirely of brass and is an excellent machine, both in design and workmanship. Very few working parts are visible, and it acts almost without noise; the sliding valves, or rather sliding pistons, which regulate the engine's action, being also moved by water-pressure.

The other example, at Freyberg in Saxony, is an engine constructed by MM. Brendel in the year 1824, for draining the Alte Mördgrube mine. It has two single acting cylinders attached to opposite ends of a working beam by means of arched heads and chains; the cylinders are open at top, and have strong piston-rods of timber. The pressure of the water acts alternately under the piston of either cylinder and forces it upwards, whilst the piston of the cylinder at the other end of the beam is depressed by the weight of the pump-rods. A bell crank attached to each piston-rod gives motion to the pump-rods, each working twenty-two pumps, placed one above the other, lying at an angle of forty-five degrees, and dividing the lift of each set of pumps into twenty-two heights or stages of about thirty feet. The engine is placed 360 feet underground. The cylinders are of cast-iron, eighteen inches in diameter, with a stroke of nine feet; and the useful effect was computed by M. von Gerstner to be seventy per cent. of the power expended. A section of one of the cylinders, showing the mode of working the valves, has been sent me by a friend at Wiesbaden, and an excellent drawing of this engine by Mr. Baker will be found at the Institution of Civil Engineers.

The first water-pressure engine used in England was erected by Mr. William Westgarth, at a lead mine belonging to Sir Walter Blacket, in the county of Northumberland, in the year 1765.

The cylinder of this engine was equal in length to the whole height of the fall of water; it was open at the top, and the water ran into the open top of the cylinder by a trough; the piston worked in a bored chamber, at the lower end, of ten inches in diameter, and was attached by a chain to the arched head of an engine beam placed above, the opposite end of the beam suspending a wooden rod, which passed down the pit to work the pump.

The column of water always pressed upon the top of the piston, but by admitting water below the piston the pressure was neutralized, and the piston was raised by the weight of the descending pump-rods. On closing the communication with the underside of the piston and discharging the water from the cylinder bottom, the pressure of the column again acted upon the piston and sent it down. By a simple and self-acting piece of mechanism, similar to the working gear of the steam-engines of that time, the orifices were alternately opened and shut, and the reciprocating motion of the engine continued.

A detailed account, with drawings of this engine, was submitted to the Society of Arts in the year 1769, and printed in the fifth volume of the Society's Transactions in 1787. The description and drawings, from which a model was then made, were given by Mr. Smeaton: the Society voted fifty guineas to Mr. Westgarth, and presented a silver medal, with their thanks, to Mr. Smeaton for his excellent account of so valuable an invention.

I have carefully examined these interesting memorials of the early encou-

ragement given to inventive genius by the Society of Arts, which continues with renewed energy its career of public utility under the presidency of Prince Albert. I am satisfied, not only from the evidence which the machine itself offers, differing as it does entirely from any of the German engines, but from the written testimony of Mr. Smeaton, that Mr. Westgarth's pressure-engine was his own invention; and that he borrowed no part of it, either in plan or in detail, from anything then or previously existing on the continent. His idea appears to have been taken from the single-acting, open-topped atmospheric engine of the period; substituting the pressure of a column of water for the pressure of the atmosphere.

The liberality and goodness of heart which distinguished Mr. Smeaton, no less than his high talent and skill as a civil engineer, appear conspicuously in the correspondence alluded to, from which I have thought it requisite to give the following extracts:—

"Austhorpe, April 29, 1769.

"I had the pleasure of seeing the first complete engine of this kind at work in the summer of 1765, for draining or unwatering a lead mine belonging to Sir Walter Blacket, at Coldcleugh in the county of Northumberland; since which time that machine has been shown to all those who had the curiosity to see it. Mr. Westgarth has now erected four others in the different mines of that neighbourhood, one of which I have seen, and all attended with equal success."

In a subsequent letter Mr. Smeaton says,—

"Mr. Westgarth was induced to think of applying for a patent for the exclusive privilege of using this invention, but previous thereto he was pleased to advise with me concerning it, being at that time frequently in these parts of the country as an agent of Greenwich Hospital.

"Much as I admired the ingenuity of Mr. Westgarth's invention, I dissuaded him from the thoughts of a patent, as it would take a length of time to be sufficiently known, and the number of cases in which it could be properly applied were not sufficient to afford such a number of premiums as might defray the expense of a patent, with a prospect of advantage to himself and family.

"I therefore recommended it to him, as the Society for the Encouragement of Arts, Manufactures and Commerce were, by handsome premiums and bounties, encouragers of all useful inventions and improvements, to communicate his invention to them, that it might be made public, in confidence that he would obtain a bounty for the same of such value as to the Society should seem meet; and in consequence hereof I gave him a representation of the utility of his invention, with which in the year 1769 he applied to the said Society, and obtained a bounty upon condition he delivered to the Society a working model and a draught, showing the construction of the engine; but as the death of Mr. Westgarth, which happened not long after, prevented the usefulness of the machine from being so successfully spread, as it doubtless otherwise would have been, and as some of the most essential parts of the machine cannot be seen in the model without its being taken to pieces, and the drawing not being accompanied with any literal explanation, nor the details of it sufficiently made out, at the request of the Society I have now supplied these defects, that it may be published in such a manner that the utility of it may be seen, and the means of making and applying it be explained."

It appears that on seeing Mr. Westgarth's engine, Mr. Smeaton suggested to him that if the engine instead of the great lever or balance-beam were made to work with a wheel, and instead of the long spear going down the

descending pump trees, the pistons were made to communicate with the main chain through a collar of leathers or stuffed collar, that then the whole of the machinery would stand together just above the level or sough, and there would take up less room, as the work might in general be comprehended within the limits of the shaft; and the descending pipe might also be of a less bore and be fixed in a corner of the shaft, and therefore be upon the whole much more convenient for underground works; and in this mode the latest engines of Mr. Westgarth were actually constructed with success. So that little was wanting, except the perfection of modern workmanship, to render the engine complete, although it was not made direct-acting, as the engines recently made generally are.

Mr. Smeaton constructed a water-pressure engine in 1770 at Temple Newsam, Yorkshire, to work a pump for supplying Lord Irwin's residence. It was of course of small size, and the pressure being communicated to the cylinder by an inclined pipe bringing the water from some distance, he modified and improved the plan of Mr. Westgarth, closing the cylinder top and using the piston-rod with a stuffed collar, still however retaining in its original form, or nearly so, the ingenious slide valve devised by Mr. Westgarth.

This was a cylindrical hoop or ring, sliding for a short distance up and down upon a pipe, which it encircled, the pipe having two sets of openings separated by a horizontal bridge or partition. The valve was inclosed in a box attached to the branch pipe of the cylinder, and sustained the pressure of the column equally in all directions; and it was rendered water-tight by strips of leather.

When the upper openings in the pipe were exposed above the valve, the water entered the cylinder below the piston, but when the lower set of apertures was opened by raising the cylindrical valve, the water escaped from the cylinder, the position of the valve at the same time shutting off the further entrance of the water and its pressure upon the piston. The openings were in the first instance square holes, but afterwards they were made in the form of a lozenge or rhombus, with the acute angle upwards, so that the water might enter or be shut off more gradually.

After Mr. Smeaton's time the water-pressure engine seems to have remained in abeyance, and I am not aware that any more of them were made until Mr. Trevitheck revived their use. The great improvements made in the steam-engine by Mr. Watt caused water-engines of all kinds to be neglected; and even water-wheels were in many cases replaced by steam-engines as their substitutes. Water power went out of fashion, and was generally considered to be too precarious and expensive, as compared with steam, to deserve much attention from engineers.

Lately, however, more enlarged views have been taken respecting water power, and the subject has been more studied and better understood. Instead of depending on the uncertain flow of streams and rivers, sometimes flooded and sometimes dried up, water has been stored in vast reservoirs, collecting the surplus rain from higher ground and ensuring a constant supply at all seasons, thus rendering water power both certain and cheap. The Bann reservoirs in Ireland and the Shaws water-works in Scotland may be taken as examples of this kind well-worthy of imitation.

Mr. Trevitheck constructed several water-pressure engines, one of which was erected in Derbyshire in the year 1803, and is still, I believe, at work at the Alport mines, near Bakewell, to which it was removed from its original situation, not far distant.

Through the kindness of Mr. John S. Enys of Penryn, I have been favoured with extracts of letters from Mr. Trevitheck to Mr. Davies Gilbert,

referring to the "great pressure-engine in Derbyshire." In one of these, dated January 10th, 1804, he says, "It has been at work about three months and never missed one stroke, except when they let a tub swim down the descending column."

This it appears damaged the cylinder cover, which was speedily repaired and the engine again set in motion; for in a subsequent letter he complains of non-payment for his foreman's attendance and travelling expenses and for the wages of the men he sent, adding, "If they found fault with the engine there would be some reason for not paying, but they say it is the best in the world."

The cylinder of Mr. Trevitheck's engine is, I believe, thirty inches in diameter.

In 1841, our respected Treasurer, Mr. John Taylor. advised the application of another and more powerful engine at the Alport mines, which was made under my direction at the Butterley Works. This was the most powerful engine that had been made: the cylinder is 50 inches in diameter and the stroke 10 feet. It is worked by a column of water 132 feet high, acting below the piston and lifting by direct action a weighted plunger pole 42 inches in diameter, which raises the water from the mine to a height of 132 feet, so that the proportion of power to effect is as the area of the piston to that of the plunger, namely, 1963 to 1385. or full 70 per cent. (see the three figures, Plate I.).

I received a letter a short time ago from Mr. Darlington, who has the care of the machinery at the mines, and who fixed this engine, in which he says the engine has never cost them £12 a-year since it was erected.

The usual speed is about five strokes per minute, but it will work at the rate of seven strokes without any concussion in the descending column; the duty actually done being then equal to 168 horses' power. of 33,000 lbs. raised a foot high in a minute. Thus, the area of the plunger, 3 feet 6 inches in diameter, is 9·621 square feet × 10 feet, the length of stroke, × 7 strokes per minute = 673·47 cubic feet of water raised 132 feet high in a minute; and 673·47 cubic feet of water × 62·5lbs., the weight per foot, × 132 feet in height = 5,556,127, which, divided by 33,000, gives 168⅓, say 168 horses' power. The pressure upon the piston from a column of water 132 feet high, reckoning 27 inches of water equal to a pound, is about 58 pounds on the square inch. or rather more than 50 tons pressure on the area of the piston. Thus, the area of the piston, 50 inches in diameter, is 1963 square inches × 58lbs. = 113,854, and this divided by 2240. the number of pounds in a ton, gives 50·8, say 50 tons.

This engine was erected early in 1842, and has been at work without intermission for more than six years. On one occasion, when I made inquiry about it, I was told that it had been constantly going for the last seventeen weeks, and nobody had seen it during the time.

An excellent model of this engine will be found in the museum of Economic Geology, made by Mr. Jordan, since so well known by his invention for carving wood by machinery.

It will be observed that after the large valves are closed, the pressure is continued upon the piston to complete the stroke. This was at first done by means of cocks at the sides, but as the friction of these caused some little trouble, Mr. Darlington substituted some small pistons to shut off the water at the termination of the stroke, and at the same time made the openings a little larger.

Mr. Taylor has since, I believe, had another engine of the same size made for a lead mine in Wales, and the result has been equally satisfactory.

I beg leave to submit this subject to the Association as one worthy of notice, observing that in this case, as in all others where water acts by its gravity or pressure, those machines do the best duty where the water enters the machine without shock or impulse and quits it without velocity. We then obtain all the available power that the water will yield, with the least loss of effect, and this result is best accomplished by making the pipes and passages of sufficient and ample size to prevent acceleration of the hydrostatic column.

Description of the Figures.

The three figures given in Plate I. show an elevation, plan and section of the water-pressure engine at the Alport Mines. The arrows show the entrance and escape of the water which works the engine. The influx and efflux are regulated by two sluices, which are raised by screws, and determine the speed of the engine and of the up and down strokes of the piston.

On the Air and Water of Towns.
By Robert Angus Smith, *Ph.D., Manchester.*

Having been requested to examine into the variations in composition of the air and water of towns, I send the observations which I have made upon the subject.

It has been long believed that the air and the water have a most important influence on our health, and superstitions have therefore constantly been attaching themselves to receptacles of the one and emanations of the other. The town has always been found to differ from the country; this general feeling is a more decisive experiment than any that can be made in a laboratory. Although men of high standing have been found to deny that any difference exists between the air of the worst towns or the most crowded rooms and that of the open country, it seems to be only a proof, that men accustomed to experimental inquiry are apt to forget the value and force to be attached to those apparently less rigorous observations which the senses are constantly and unconsciously making, and to believe only that which can be demonstrated by the grosser processes of a laboratory. Most men would be satisfied of the impurity of an atmosphere through which a blue sky could never be seen of a blue colour, or where a bright cloud appears of a dingy brown; but there are men who take this air into glass receivers, and because they detect no new substances or strange compounds, they deny that there is any peculiarity. I have known persons from the highlands of Scotland who felt in going into Glasgow as we do when going into a glass-house or forge, and who could not be persuaded to stay, unless they remained long enough to find some advantages before unknown to them. The inquiries made by the Sanitary Commissioners have completely established the fact that crowded towns are dangerous places; and although it is still an open question whether a well-regulated town or country life be the more healthy, it is sufficiently established that our towns have subjected themselves to many dangers, which we in self-defence are feeling compelled to try to avert, by acting according to natural laws as far as their acquaintance has been made.

Most persons must have felt that a rapid entrance into a large town, especially a manufacturing town, was also an entrance into another climate. An inhabitant of the sea-coast or of the hills perceives it rapidly, and the effect on them is often decidedly bad; to those accustomed to it a few hours are found to be enough to cause them to forget the atmosphere which in their holiday excursions had caused them such delight. We are apt in

these cases to assign other reasons for the feelings experienced, and to attribute much to the change of scene and occupation; and I have read it not long ago asserted, that the air in the streets of London and of the tops of distant hills probably differed only in the temperature.

Priestley found that after shutting up a mouse in air a considerable time it seemed to become weak and to be slowly dying, but if he put a fresh mouse into the same air at this period it instantly died. We can bear the gradual deterioration with ease, but we often find ourselves surprised at the state of the air in which we find our friends sitting, perfectly unconscious of any want of attention to their sanitary state.

The air has often been called a general receptacle for all impurity; Nature has made it a universal purifier by giving it so large an amount of free oxygen. It is oxygen which purifies, and bodies which are impure have a tendency to volatilize, after which they become pure.

No doubt the air of a town contains a portion of all exhalations which arise in a town. These are such as come from living bodies in the first instance; exhalations which can never be got rid of, but which it is probable are not at all dangerous, unless accumulated. There are also exhalations from the refuse matter of animals, and from combustion of fuel. These are the chief points. Various manufactures give out various effluvia, and no man that has walked through a large town with attention can have failed to perceive that no street is entirely free from effluvia, and that every one seems to have a peculiarity of its own.

The smell is a delicate guide to this, and although custom causes us to forget that odour to which we are much exposed, a frequent change gives us still more acuteness, and both houses and streets may fairly be complained of when the inhabitants are little aware of it.

That animals constantly give out a quantity of solid organic matter from the lungs may readily be proved by breathing through a tube into a bottle, when the liquid or condensed breath will be collected at the bottom of the bottle; or by breathing through a tube into water, when a solution of the same substance will be found in the water. This would scarcely require proof if we considered that breath so frequently has an organic smell; perhaps rather it always has an organic smell, and when it is bad the smell is often offensive, containing decomposing organic matter.

If this condensed breath be put on a piece of platinum, or on a piece of white porcelain and burnt, the charcoal which remains and the smell of organic matter will be conclusive. If it be allowed to stand for a few days (about a week is enough), it will then show itself more decidedly by becoming the abode of small animals. These are rather to be styled animalcules, and very small ones certainly, unless a considerable quantity of liquid be obtained: they may be seen with a good microscope. Animalcules are now generally believed to come from the atmosphere and to deposit themselves on convenient feeding-places; that is, they only appear where there is food or materials for their growth, and they prove of course the existence of that continuation of elements necessary for organic life. At the same time their presence is a proof of decomposing matter, as their production is one of the various ways in which organized structure may be broken up. Such a liquid must of course be an injurious substance, giving out constantly vapours of an unwholesome kind.

I mentioned some time ago that I had got a quantity of organic matter from the windows of a crowded room, and I have since frequently repeated

the experiment. This matter condenses on the glass and walls in cold weather, and may be taken up by means of a pipette. If allowed to stand some time, it forms a thick, apparently glutinous mass; but when this is examined by a microscope, it is seen to be a closely-matted confervoid growth, or in other words, the organic matter is converted into Conferv æ, as it probably would have been converted into any kind of vegetation that happened to take root. Between the stalks of these confervæ are to be seen a number of greenish globules constantly moving about, various species of Volvox, accompanied also by monads many times smaller. When this happens, the scene is certainly lively and the sight beautiful; but before this occurs the odour of perspiration may be distinctly perceived, especially if the vessel containing the liquid be placed in boiling water.

My analyses of this body are not yet ready, further than that it contains the usual organic elements.

If air be passed through water a certain amount of this material is obtained, but I have found it difficult to pass a sufficient quantity through. If it is made to pass rapidly, absorption does not take place, and evaporation of the water is the consequence; if it passes slowly, it requires many weeks to pass a hundred cubic feet through a small quantity of water. I continued the experiment for three months, but although I obtained sulphuric acid, chlorine, and a substance resembling impure albumen, I did not get enough to make a complete examination; and indeed this could not be expected, as I found that in that time less than a thousand gallons of air had passed through.

When this exhalation from animals is condensed on a cold body, it in course of time dries up, and leaves a somewhat glutinous organic plaster; we often see a substance of this nature on the furniture of dirty houses, and in this case there is always a disagreeable smell perceptible. I have no doubt that this is a great cause of the necessity for constant cleaning, which experience has found and made to be a very general practice in England and elsewhere. In other words, it is a reason why that which is not cleaned becomes dirty, a question which I have often felt great difficulty in answering.

Water is necessary to the spontaneous decomposition of animal matter, and it is probable that in a warm climate this coating of walls and furniture would not be so dangerous as with us, where everything is exposed to moisture a considerable part of the year. In a warmer climate it will probably be diffused more into the atmosphere, and not be so much retained as it is by the moisture which dissolves it or to which it attaches itself.

It will probably be found that this substance is not poisonous if taken into the stomach, but it is known to be poisonous breathed into the lungs, as we know crowded rooms are. The quantity is small that we do breathe, but at the same time we must remember that it is diffused in air, and has therefore a surface as extended as the volume of the air in all probability; and we know that a cubic inch of sulphuretted hydrogen will scent at least some hundred cubic feet of air.

As this substance of which we speak is organic and contains carbon hydrogen and nitrogen, with other elements, it is capable of oxidation; and it no doubt is continually undergoing oxidation in the air, probably forming carbonic acid, water and ammonia. It is also not unlikely that this is a greater source of the ammonia of the atmosphere than the mere fœtid decomposition of animal matter, which does not occur to a large extent in nature, provision being made for its removal by animals, and by vegetation especially.

Organic matter in contact with water constantly gives off an odour of some kind, and especially if heated, so that it would appear as if steam or vapour were capable of taking up much more than that which we call volatile matter.

If organic matter be allowed to decompose in the air it gives out carbonic acid, ammonia, sulphuretted hydrogen, and probably other gases. Priestley has shown that if it decomposes in water it gives out an inflammable gas. If however it be exposed to the action of soil, other circumstances being favourable, it is converted partly into nitric acid.

None of these cases occur purely in our towns, but all of them occur to some extent. Carbonic acid and ammonia occur in all reservoirs of refuse, and sulphuretted hydrogen occurs also in abundance. It was once very perceptible in London, as Sir Kenelm Digby complains much of the state of the streets, when silver could not be kept clean in his day. This may be observed now in many towns, and is in fact not uncommon. This is a disagreeable smelling gas, and wherever it is abundant will be easily detected by the nose. It may be detected readily in many courts and alleys, also at the mouths of sewers, and in some parts of the Irwell and Medlock at Manchester, where they are filled with organic matter and alkaline and earthy salts. Ammonia generally accompanies it so as to diminish its bad effects.

Ammonia itself is probably of no injury unless in excessive quantities, and may be considered as one of the most wholesome forms in which nitrogen and hydrogen, as gases, pass into the air. A decomposition such as this occurs ordinarily in towns, as there is a certain exposure to air always.

In cases where there is no exposure, or at least when the substance is in water, inflammable gases are produced, as Priestley has shown and Liebig has to some extent explained. It would seem as if, when decomposition commenced, oxidation of one portion necessarily took place, leaving the other portions without oxygen, unless in cases where an abundance could be obtained. Dalton found the gas from the floating island at Derwentwater to contain carburetted hydrogen and nitrogen. The carbon and the hydrogen are deprived of oxygen entirely, whilst more oxidized bodies, as carbonic acid and humus, are left, the latter body to be in time entirely oxidized, as Liebig has shown. Whether the nitrogen comes off alone or as ammonia, the same division of a substance into oxidized and deoxidized occurs as we see in the fermentation of sugar, where carbonic acid a body oxidized, and alcohol a body to a great extent deoxidized, occur. We have only to suppose compounds of carbon, hydrogen and nitrogen, coming from decomposing matter, to show us the great danger. It is not to be trusted that these bodies always appear in the mode of combination mentioned here; their modes of combining are various, and these elements form the most active poisons known to us.

A certain amount of moisture is almost essential to the escape of odour from many bodies; it probably arises from two causes. The vapour of water is a vehicle for organic matter, and water favours decomposition in bodies, so that as they decompose the vapour is given out. From whatever cause, it will be found that moisture rapidly facilitates the escape of odour. Mineralogists avail themselves of this when they breathe on a mineral and then ascertain the smell. The moisture of an evening, or even artificial moisture, causes the flowers to give their scents, and the moist state of the atmosphere before or after a shower causes also a great fragrance in a flower-garden. But whilst this is caused the same laws are operating for injurious effects,

wherever *there is a reservoir of putrid matter, for then the exhalations* are also abundant, and bubbles may be seen to rise from filthy water. It is not improbable that the state of the atmospheric pressure may cause this, as Mr. E. W. Binney has shown that the gases in coal-pits are caused to escape rapidly during a lowering of the barometer. Bodies that are moist will therefore give out more organic vapours; if there be abundance of water, as in a lake, the vapours would to a great extent be dissolved, even if the same kind of decomposition were to proceed as in merely moist or marshy ground. We might expect then that soil, if moist, will give out, not pure vapour of water, but water with organic matter in it. Wet soil is a little acid generally, and if very acid is bad land, sour as it is called; but if made alkaline either by the direct adding of ammonia, or by decomposition producing ammonia, it becomes fertile. If any alkali be added which gives out ammonia by decomposing the humate of ammonia in the ground, the same state of fertility is attained. This end is generally attained by adding lime. This state of almost neutrality of the soil is also regulated by nature, and a fertile alkalinity obtained by the rapid decomposition of organic matter through moisture and heat. In this alkaline and warm state more vapours will of course be given off, and the ammonia will assist in the removing of organic matter into the air. How far this occurs on sowed land has not yet been seen by me satisfactorily; but on peat land the ammonia formed is abundant in hot weather, so much so as to be perceptible directly by the senses, and to take with it in solution a large quantity of humus and salts of humus, containing food for plants, as I showed in a paper to the Philosophical Society of Manchester.

I mention this to show how organic matter may be lifted into the air, and why hot weather promotes it; also I wish to show how various this matter must be in its properties, as all vegetable solutions give out a certain amount of matter from them.

To ascertain if organic matter were really to be got from such vapours from land, I collected some dew by condensing it on a glass cylinder, and allowing it to drop into a glass below. The fewness of the evenings favourable for the purpose this year has of course retarded me. I saw plainly however that the substance thus obtained from the dew was very different from that obtained by condensation in a warm room; whereas that from a crowded room was thick, oily, and smelling of perspiration, capable of decomposition and productive of animalcules and confervæ; the dew was beautifully clear and limpid. When boiled down the odour was not disagreeable, and I may say not remarkable; but when the small portion of solid matter which remained dissolved in it was exposed to heat, the smell was that of vegetable matter with very little trace of any nitrogenized substance. It was also rather agreeable than otherwise. The dew was collected in a flower-garden, and I have no doubt in favourable weather of being able, in dissimilar situations, of getting it of different characters. It is not improbable that the matter in the dew may be a measure of the amount in the atmosphere; if so, the decided difference between that of the country and that of crowded rooms is to be remarked, and may probably form a good guide towards a knowledge of comparative purity of atmosphere.

In walking along the fields on an evening when there is much dew, it may be observed how much effect a dry soil has; indeed I might almost say the climate of a field will be found to vary almost every yard. Every cause of cold, the formation of a drain, the lowness of any spot, its being higher or more level or more sheltered, is indicated by this delicate ther-

mometer, the rise of vapour and the perception of cold. If we ascend higher the same is seen on a larger scale—on miles instead of yards. A house may be in a clear atmosphere and the lawn before it in an impenetrable fog. One foot in height makes a difference, and one foot also of level distance, if the ground should differ in quality. The damper places give us a feeling of freshness, and cause also a slight irritation of the nose. Every wall causes a certain amount of dampness; and even in a windy day, a leafless hedge will protect one side from evaporation. In these respects therefore we may say truly, that every field or house in the country, as well as I believe every house in the town, has its own peculiar climate.

The effect of wetness on the atmosphere of a town is very great; if we observe the smoke on a dry day we find that it rises, and if there be a little wind it is carried out in distinct black lines, leaving the air below comparatively pure. If the day be dull and wet, the smoke instead of being carried away is poured out directly into the streets, and a spectator at a short distance sees a basin of black fluid, if the town be in a valley, or a heap gradually diminishing towards the circumference as it falls into the adjacent country. It may be replied that the diffusion of gases would prevent this, but again it may simply be said that it does not prevent it. Besides, the smoke is not to be considered as a gas, the black portion is carbon and tar. If the carbon is wet, it becomes, like all other spongy bodies when filled with water, heavy, and of course falls down. The carbonic acid will no doubt be diffused more, but it also is strongly attracted by water, and must not be viewed as a pure gas, such as oxygen or nitrogen. Probably this is the reason of the very disagreeable state of our towns in damp gloomy weather; it is such weather as does not allow the town to be ventilated. The same does not occur on a thoroughly wet day, when the matter is carried fairly down into the streets, and a certain freshness is perceived.

Rain amidst smoke is just such a liquid as we might expect; it is a mixture of soot in a finely-divided, apparently dissolved state. It is however not dissolved, and by boiling down may be got free. It is not easy to tell exactly the composition of the rain; for although I have examined it and obtained many products in it, so much may be said to come from other sources when water is collected near houses or near the ground, that I have often suspected some source of error. However, I think if we take that rain which is collected on a very wet day, after many hours of continued pouring without wind, we may consider that we have got the purest specimen. This was collected frequently, and having obtained it so often I am now satisfied that the dust really comes down with the purest rain, and that it is simply coal ashes. No doubt this accounts for the quantity of sulphates and of chlorides in the rain, and for the soot, which are the chief ingredients. This rain is also often alkaline, arising probably from the ammonia of the burnt coal, which is no doubt a valuable agent for neutralizing the sulphuric acid so often formed. It must however be frequently acid with sulphuric acid, although I have not found it so, as I have traced sulphurous acid in the atmosphere frequently, walking through some miles of streets to come to its source. The source however is not easily obtained, because I believe it does not fall till at some distance.

The rain-water at Manchester is about 2¼ degrees of hardness, harder in fact than the water from the neighbouring hills, which the town intends to use. This can only arise from the ingredients obtained in the town atmosphere.

But the most curious point is the fact that organic matter is never absent, although the rain be continued for whole days. This matter is capable of

promoting animalcular life to some extent, and small specimens may be seen moving solitary in it. If allowed to stand in a bottle, this may be more clearly detected. On this matter I must say more at a future time.

My chief wish is to show that the general notions entertained by persons as to the air of towns are not without the support of what is called scientific observation, although at the same time the effects on life are greater than chemists by any observations could have made out.

Vogel and others have found organic matter in the atmosphere; and Dr. Southwood Smith, in looking for matter which might produce fever, found an organic substance, I believe, in some of the streets of London. I give only in detail what I have myself observed.

If this matter should from any cause be exposed to a decomposition more rapid than usual, we have before us a state of things worse because more general than a bad sewer, and can account for many diseases. I am therefore disposed to think of it as Lord Bacon thought of the cause of jail fever :—"Out of question such smells consist of man's flesh or sweat putrefied. There may be great danger of such compositions in great meetings of people within houses; for poisoning of air is no less dangerous than poisoning of water. And these empoisonments of air are more dangerous in meetings of people, because the much breath of people doth further the reception of the infection."—Bacon's *Sylva Sylvarum*.

The state of the air is closely connected with that of the water; what the air contains the water may absorb, what the water has dissolved or absorbed it may give out to the air. Whatever the rain meets with in its course from the surface to the wells of a town is, if soluble, dissolved in the water. The enormous quantity of impure matter filtering from all parts of a large town into its many natural and artificial outlets, does at first view present us with a terrible picture of our underground sources of water. But when we examine the soil of a town, we do not find the state of matters to present that exaggerated character which we might suppose.

I have often been struck with the extent to which water may purify itself. At Bala, on the hills, the water is brown; in the lake it is still coloured, but in its course it becomes beautifully clear. A still stronger instance may be observed on the hills beyond Bolton, the water in which is of a deep brown: when it falls into the reservoirs just below it ceases to be very dark, although still too brown for agreeable use; but when it has run a few miles it ceases to be remarkable, and is often perfectly pure. I was struck also with the fact that filters do not become dirty in proportion to the amount of impurity which they seem to remove. The sand at the Chelsea waterworks contains only 1·43 per cent. of organic and volatile matter after being used for weeks, and cannot be considered as impure in a high degree.

In 1827 Liebig found nitrates in twelve wells in Giessen, but none in wells two or three hundred yards from the town (Annales de Chimie, vol. xxxv.). Berzelius made similar observations at Stockholm. In 1846 and 1847 I examined about thirty wells in Manchester, and found none free from nitrates; many contained a surprising quantity, and were very nauseous (Mem. of the Chem. Soc.).

Wells in the country generally contain organic matter, and in the town the organic matter is oxidized into nitric acid, as if it required a certain intensity to promote the action. It is very probable that this acid is an effect of restricted oxidation, occurring as it does with such excess of organic matter, and, although near the surface, still under hard pavements

and soil where there is also little flow of water. It might however be viewed as an oxidation, with excess of oxygen also where the large extent of surface presented by the porous materials gives an increased facility for oxidation, or rather presents compressed oxygen, so as to be more effective.

It will be of interest to know what becomes of the carbon and hydrogen in these cases, if they are removed together. These nitrates do not occur to any extent in purifying large bodies of water, nor do they occur in filtering through rocks or sand as in nature, but they occur in more close situations, under streets and houses and in undrained ground, according as it is saturated with animal matter. It is found in sewer water, in the Thames water, and in all dirty streams into which sewers empty themselves: perhaps the reason of its not being found in larger quantities in streams from drained land is simply the want of animal matter, or it may not be formed more rapidly than the plants can use. It is found however in wells which are situated in well-manured gardens, and in all wells at the backs of houses, without any exception, yet met with by me.

The wells of private houses, and we may say wells generally, are placed in that spot which of all others is the worst, the cesspools and the wells always too near, generally close to each other. I was first led to examine this from a complaint made in Manchester, where a case of this kind furnished water of an oily appearance, containing about 90 grains of matter in a gallon, and being excessively disagreeable. The same well was examined in summer, and the matter had risen up to nearly an ounce in a gallon. The well was of course not fit for use in this state.

In the same neighbourhood was a churchyard, and around it I examined five wells, one of them especially, sufficiently far removed from cesspools to make me believe that the churchyard was the only cause of the impurity. The wells of London all contain nitric acid to a certain extent, but they vary exceedingly in the amount. The following have only a small quantity:—Exchange, Rood Lane, Eastcheap, St. Paul's Churchyard, Tower Hill, Covent Garden, Lincoln's-Inn Court, St. Clement's, Strand, Aldgate Pump, and Bow Church. It seemed to me from the situation of the old well at Clerkenwell, that it was very well fitted for obtaining nitrates, and on examination it was found to be exceedingly well-filled with earthy salts, containing 148 grains of solid matter to the gallon, of which several were nitrate of lime. The water of this neighbourhood would contain about 20 grains to the gallon in a natural state, if we may judge from the water generally found in the valley of the Thames.

Another well in North Street, Tottenham Court Road, was examined, as from the state of the drainage I expected it to contain a considerable quantity of earthy salts. Here also I was not deceived, having got 130 grains of sulphates, chlorides and nitrates in a gallon; the water itself a fluid which I could not swallow.

There is then a constant formation of nitric acid under towns. It is a little surprising that organic matter, properly so called, should not be found in those wells; the nearest to a source of organic matter do actually contain the least, because in these cases it is more readily converted into nitric acid, which may very properly be called here oxidized organic matter. At the same time also it must be remembered, that the nitrates decompose any organic matter present if heat be applied, so that no blackening of the residue can be perceived. Those wells of London first mentioned do not contain much of these salts, but sufficient to deprive them of organic matter,

as no vegetation is to be perceived in them, even by a microscope, after a long period.* If however a mere trace of nitric acid be found, as in the well of Tower Hill, a green matter deposits on standing. This perfect freedom from animal or vegetable growth is a ground for suspicion also of nitrates being present, as there generally is a little green matter found in the purest waters, unless they pass through great depths of sand or gravel, as in the new red sandstone, where the water, if taken from a deep well, is entirely free from everything but inorganic salts.

The fact of some of the wells being freer than others from these salts is a proof of a dependence on the state of the soil, and I doubt not that the drainage has the greatest effect on the change made. Some of the mud taken from under a street in Manchester, where a sewer had been allowing some moisture to ooze out, was found to contain nitrates also in considerable quantities, but the sand and gravel below was nearly dry and perfectly free from nitrates. Although it is very probable that nitric acid is formed most readily in the sand, yet it is also more rapidly carried away, and after much rain we cannot expect to find such a soluble salt remaining.

As to the source of this acid, I made some experiments last year for the Metropolitan Sanitary Commission, which I may here relate. My object was to get an idea of the nature of filtration. A jar, open at both ends, such as is used with an air-pump, was filled with sand, and some putrid yeast, which contained no nitric acid, was mixed with pure water and poured on the sand, allowing it to filter through. The product of nitric acid was abundant, so much so, as when boiled down to give it out at once, on the addition of protosulphate of iron and sulphuric acid, making the red fumes of the peroxide of nitrogen apparent without the aid of any very refined test.

Charcoal was tried for the same end; it did not answer, although allowed to act for two months; it was put into a large Hessian crucible, and the liquid allowed to trickle through the crucible and charcoal together.

Ox-flesh was in this manner oxidized into nitric acid, after allowing it to putrefy. This result could be obtained by means of an ordinary household filter, if the time allowed were long enough and other conditions favourable. The same was done on a smaller scale, by allowing nitrogenous organic matter to stand over spongy platinum.

No doubt this is a very important provision of nature for the prevention of the evil consequences of putrefaction; it is the complete destruction of all dangerous gases and the perfect purification of the most impure substances; whether it be advisable to drink water having much of this oxidized matter in it is another question. We see however in this the two great agents of sanitary improvement at work for us, the air and the water acting through the soil; whatever goes through such an ordeal is made pure. The drainage of a country is therefore that which removes the evil effects of decomposition, as well as the excess of moisture.

The action of air and water on *surface* is then a powerful one, and probably is capable of doing many marvellous things with the substances given to it to treat. The effect produced on sulphuretted hydrogen is no less decided. A bottle of strong sulphuretted hydrogen was poured upon the sand-filter, and sulphuric acid was the result, with sulphates formed of bases which it had washed out of the sand. Sulphuret of ammonium filtered through sand contains sulphuretted hydrogen no longer, and will not blacken lead, so powerful is this kind of oxidation.

Water from a pump in a yard not far from me, gave out a disagreeable

smell of sulphuretted hydrogen, which filled the neighbouring houses. This I found the persons accustomed to filter and to drink: the sulphur was converted into sulphuric acid, and the water was actually made quite pure.

These are no doubt some of the advantages of a filter; if so, we are then to consider that a filter acts according to its cubic dimensions and not by its surface only. If the porous rocks have thus the power of oxidizing sulphur and nitrogen, we may then ask, have they not also the power of oxidizing carbon? Hydrogen is no doubt oxidized, the ammonia being broken up so as to form oxides, as nitric acid and water.

We see that natural filtration, with abundance of room and free movements, dissipates the organic matter, and nitric acid too, if ever formed. The time allowed for filtration being so short, that is, the time from the falling of the rain to the appearance of the pure water from the spring, we cannot suppose that vegetation accomplishes the purification, whilst there is no deposit of impurity apparent to account for the change. It seems to me that the action of the compressed air on the surface of bodies is sufficient to answer this question, and that this matter is removed by a process of oxidation. It was Saussure who showed that humus can unite oxygen and hydrogen; Liebig has shown that humus is constantly capable of combining with oxygen, and calls it a constant source of carbonic acid. When then we see water not very free from organic matter enter a rock and come out free from organic matter and sparkling with carbonic acid, leaving no visible organic impurities behind it, we may safely conclude that the oxidation of the carbon has effected it; this then is a higher degree of purification than the oxidation of the nitrogen, which is probably allowed to go free.

Processes such as these are going on constantly wherever water is filtering. On land generally such things must be constantly occurring. The ditch-water of our fields is a very different water from the river-water into which it runs, or even of the drains a few feet only below it. Some water taken from a ditch in the neighbourhood of Manchester became in a few days a complete mass of life, and the many specimens of animalcules in such water make it a good subject of study. Water from a drain three yards deep does not however contain this immense quantity of organic or organizable matter, depositing only some green matter, partly animal, partly vegetable.

When water flows from hills or elevated land in a river-course, it undergoes changes according to the nature of the bed, and also according to the number of towns on its banks. As an instance of this, I will follow the river Thames from its sources to London Bridge without giving the details of analysis here, but the character of the changes as known to me.

Water from the Seven Springs or from Thames Head or Andover Ford, proceeding as it does from the rock, is in the perfectly oxidized state of which we have been speaking; it contains a great deal of carbonic acid and of lime in solution. When allowed to stand, it preserves its great purity (or clearness of appearance rather) any length of time, not appearing to change. Such water as this requires no managing; it would be a good thing if it could at once be introduced into houses; it is in fact spring-water from the rock, and such water is known to be always good, unless the rock contain deleterious substances. Rocks of course are found which give out a water much freer from lime than the water of the Thames sources; such, for example, as those between Lancashire and Yorkshire. At a place called Swineshaw on one of these hills a stream gushed out from the hard and insoluble rough rock of this place, having the purity of average distilled water, with a sparkling appearance and agreeableness to the palate which distilled water never

has. It is under one degree of hardness of Clark's test. No doubt there are other streams as good, and the whole of that and similar districts gives the most beautiful water. The same may be said of a great deal of the water of North Wales, and in such places as have very insoluble rocks. I said as pure as the average distilled water; it may not be known to all persons, that a number of distillations are necessary in order to obtain pure water. For this purpose, a water from a great depth, or a spring-water from a rock is best to use, as there is less volatile and organic matter in it; the first distillation of the usual waters about Manchester giving a very imperfect product.

Purity of water and fertility of soil are not to be expected together, if we may judge from the facts above. Freedom from both inorganic and organic matters is got only in water from very insoluble rocks, which are not the fittest for vegetation; or it is got where there is much sand or gravel containing little soluble matter, and of course little food for plants. If however these strata be together, as soon as the water comes from the insoluble to the soluble it will change.

The Thames water is at first pure, as far as freedom from organic matter occurs, and takes its course through a rather level country. The stream is soon filled with plants; and at Kemble the water has already taken up some organic matter, enough to form a slight green deposit on standing. The water here is still beautifully clear, and is good water; it is 15·5 degrees of hardness.

When we come down to Pangbourne, the water cannot be said to have become much worse; it is still so pure as to require a considerable time to form a deposit, and that only small, containing a few plants and some small animalcules from $\frac{1}{2000}$ to $\frac{1}{3000}$ of an inch. Here there is a slight but still decided trace of organic matter from animals. There has been an increase in the hardness also.

			Grains of Soap.
Seven Springs............	12·75	of hardness	262
Andover Ford............	13·88	,,	283
Thames Head at Kemble ..	15·5	,,	312
Church at Cirencester	15·7	,,	315
Reading	16·5	,,	340

Pangbourne was only 15·4 in November 1847; the others are of February 1848, when the water was harder down to London. There is seen here an increase in hardness, and there is also an increase in soluble salts not contributing to the hardness. At Seven Springs the hardness is equal to the whole amount of insoluble salts and a fraction more, which may arise from an excess of carbonic acid.

	Grains.
At Seven Springs inorganic matter in a gallon	12·25
At Pangbourne	22·33
At Reading	23·114

At Windsor animalcules begin to show themselves more prominently in the water, and these rather large Hydatina. There are also at Reading and Oxford some of the smaller green Naviculæ, and several other smaller green Bacillaria. Oxford water had more of these than Reading, and also a large amount of matter in solution; it is probable that the soil through which the Isis flows is rather different from the other part of the Thames. The river was rather high at the time.

From Richmond downwards the case is much altered, and the water, although

clear, gives after a time a brown flocculent deposit, entirely distinct from the mud deposit, which has been carefully removed beforehand. This flocculent deposit contains many animals, large and gelatinous-looking; also below Chelsea, and chiefly below Hungerford-market, little eels, "*Vibrio fluviatilis*," about $\frac{1}{30}$th of an inch long. The side of the vessel in which the water stands is covered with another precipitate quite distinct, not flocculent but hard, of a light brown, and chiefly towards that side of the vessel which is exposed to a moderate light. This precipitate is often mistaken for oxide of iron, which it strongly resembles, and to which it may probably owe its colour; but it may be known to differ from a simple oxide by the addition of muriatic acid, which gives it a beautiful green colour. When seen through the microscope, the colour will be found owing to the little dots of green which mark the polygastric character of these animalcules. These little creatures (chiefly I believe the "*Navicula fulva*") are covered with a crust of silica, and by boiling in muriatic acid the silica may be separated from the other portions which are soluble. In this way phosphoric acid, lime and magnesia may be separated with ease; and this will, I think, be found one of the best modes of collecting the phosphoric acid from water of this kind. The quantity of silica is very great, as the number of these little loricated animalcules prove. Life of this kind may at once be considered as a proof of the presence of all those elements essential to animal life generally, as these animalcules do not appear unless in the wreck of other animals or vegetables, whose requirements as to food are well known to be confined to certain elements. The abundance of silica is not from the upper part of the Thames, but no doubt from the sewers, proceeding from the decomposition of wheat, oats, &c., and may be viewed as a necessary consequence of the consumption of bread or any grasses used by cattle.

There is then a great deal of matter in a state capable of being converted into living forms; this matter is not in suspension merely, but in solution also. A large quantity of organic matter is precipitated in contact with clay and mud in the Thames, but a great deal is also in clear solution. This matter must be organized of course to some extent, and probably contains albumen; it seems to me that it is albumen which I have found in it, certainly a body much resembling it. The same may be obtained where many large animalcules appear; probably the quantity will be found the same whether the animalcules be formed or not. The clear solution becomes a mass of growth very soon, if the matter contained in it be organisable. Organic matter may exist in a state in which, even under favourable circumstances, animalcules are not formed, as I have found to be the case with some kept for some months in water. A similar thing may take place with the Thames water at London; if kept in close jars of earthenware no change is produced in the organic matter; as soon as removed into glass bottles, a rapid change occurs, and a lively scene is produced of animals and vegetables. Kept in the dark, the water dissolves much organic matter and becomes yellow; the water over the living matter is clear, or, in other words, the dead matter is to some extent soluble in water; living matter is of course not capable of having its parts broken up by mere water, and is insoluble. This growing of plants and animals is therefore a good mode of cleansing water, when space and time are abundant, as in the larger operations of nature, but unfitted for waterworks, where neither are very ample. The mode of cleansing used by water-companies is one employed by nature also, as all the water which falls on the soil is filtered by passing through; that is to say, it first becomes exceedingly impure, being filled with matter from

the surface, and gives a part of this out again in passing through the soil. Water becomes hard very rapidly on the surface of some land, and it is strange how it adheres to its standard of hardness, remaining for a great part of the year the very same. A rapid shower, producing a sudden overflow of a ditch in a field, was found to be composed of water of twelve degrees of hardness and sixteen grains of solid matter to a gallon; this same specimen also swarming with life.

I supposed, and others have done so also, that a shower would produce a stream of water softer than what slowly trickled through the ground; but on examining the water at Longendale in rainy weather it had actually risen two degrees. The Thames was also considerably softer in November 1847, after some dry weather, than in February 1848 after long rain. At Chelsea, in November it was 13·44 degrees of hardness, taking 275 grains of soap test; in February 14·94, taking 302 grains. It would appear that rainy weather softened the ground, and so made the matter more soluble, or the winter frosts broke up the ground and attained the same end. This latter reason is agreeable to the general opinion concerning the use of a frost, and the fact may also be taken as a corroboration of the opinion. The hard water will of course be better able to feed land with its soluble manures; or, if we choose to express it otherwise, the plants will more readily feed, finding the food more soluble.

However true it be that all soil filters water, it is no less true that any admixture of clay is detrimental. The clear streams are found in rocky countries, and, as was before mentioned and well-known generally, on barren land.

We have seen that the water of the Thames at London is capable of decomposing with the disagreeable products alluded to, and when put in casks for sea use we hear of a fermentation, with the formation of nauseous vapours, and of an inflammable gas. We have already seen that Priestley found inflammable gas from organic matter decomposing in water, and, in fact, it is a thing universally observed. Priestley said, however, what is not so much observed, that the air from the decomposition of a cabbage in the dark was inflammable, whereas that in the sun produced very little inflammable air, and was not so offensive in smell. The fermentation of water may in fact be looked upon as a simple proof of great organic impurity. Organic matter will decompose either by going into inorganic gases, as in the dark, or into organized bodies of another description, if there be light to favour growth. These considerations bring us to the mode of storing water, and of supplying water to houses. If there be a large supply of water in a reservoir, it will, if impure, clear itself by vegetation, according to what we have seen by experiment, and as is seen in nature. In this case a reservoir must not be underground but in the light; strong light and great warmth seem too much to assist chemical solution, the reservoirs should therefore not be so shallow as to allow this. However, there are probably few cases where water is to be so long stored; as to the usual cases, it may be said, that unless long storage is allowed, it is better that there should be as little as possible, unless the water is to be filtered before delivery. The reason of this is, that the course of purification of impure water is the worst state of all; even filtered water will not bear standing, because it also tends to purify itself still more by giving out in some form or other all its organic contents; and it is remarkable how the apparently purest water will deposit impure matter.

The same thing may be said of water stored on a smaller scale, as for private houses, there is no way of keeping it clear. If kept dark and cool the

change is retarded, and this is the best way for small quantities. It would be the best way for large quantities also if it were perfectly pure, as then no change whatever could occur.

But even when water is to be kept a day only there is an objection to cisterns in most cases. If there be a little impurity deposited, the daily increase soon makes it a great impurity; and although the fact of the impurity remaining in the cistern be a sufficient proof that it has not been drunk or otherwise used, yet such a reservoir of impurity is constantly apt to be giving off some offensive matter. If the impurities be of the kind common in Thames water, and in the water of many of the companies, or in the Manchester water, or that of some other towns, they are of a kind capable of producing animals very disgusting, and large enough to be seen sometimes by the naked eye. If even nothing but a green matter is perceptible, this is unpleasing in itself, besides never being alone, but inhabited by numerous little creatures visible with a microscope, although not so disgusting as those to be met with in the flocculent precipitate of the Thames water. Underground cisterns in London, when supplied with very pure water, contain in them some of the most disagreeable of these living forms; and although apparently a good method of keeping water cool, it is a plan to which the impossibility of cleaning is a great objection. Even stone cisterns, however clean stone in itself may be, are often filthy receptacles of water, for which not the stone but the water is to blame. If wood be used pure water can never be obtained; and the enormous amount of crenic acid formed, with the peculiar smell of rotten wood, which happens even in new barrels, form great objections. The reddish flocculent matter is also not without inhabitants, for which it affords a good shelter.

If I come to the conclusion that water should either be kept in large quantities or kept constantly running, it may be said this was known to every one; true, but when this happens, it is the business of science to explain why it is so; and if this be not done, there are constantly found some who deny the general impression until a proof be obtained.

Dr. Clark, who has done so much towards giving the country in general an interest in the purification of water, advises also the alkalinity of the water to be taken at the same time as the hardness. I have found it more convenient to take the fixed contents in a gallon of water. By comparing this with the hardness, we find the excess of impurities not affecting the hardness. To do this and take the alkalinity also, would probably be the best mode of treatment. In the springs at the source of the Thames the fixed matter and the hardness are equal, or nearly so, whilst in the Thames at London, the fixed matter rises as high as twenty-six grains per gallon, whilst the hardness is fifteen degrees. This gradual increase of salts not affecting the hardness is a good indication of the rate of impurity in the progress of the river, and is a great cause of making it a less agreeable draught.

From experiments which I have made on the cause of vapidness in water, I am led to believe that the salts of alkalies are some of the most common agents. Dr. Clark has shown the great influence of temperature on the taste of water, but it seemed to me not enough to explain the frequency of the occurrence of tasteless water.

Water with carbonic acid in it did not taste vapid when raised slowly to 100° Fahr., the acidity being sufficient to prevent it, as I believe.

Lambeth water boiled and cooled could not be made to taste as well as water which had not the same amount of salts in it.

Pangbourne water, although excellent, when boiled down so as to saturate

the salts which are not precipitated by boiling, tasted even when cooled excessively vapid.

Soda-water with alkaline salts, when boiled, is excessively disagreeable.

Twenty grains of common salt cause a gallon of water to taste vapid, and two grains and a half of saltpetre or nitrate of potash have a still stronger effect.

The nitrate of lime in the water of towns mixed with the common salt gives an extremely nauseous taste to water, and causes it also to taste somewhat soft, although possessing such a large amount of matter as I have mentioned. Acids control this taste; carbonic acid, we have seen, prevents vapidness. A few drops of any acid render water pleasanter in a warm day. Acidity is strongly allied to coolness of the taste, as general experience shows. Acid drops and oranges in hot rooms are used for this reason, and vinegar also by travellers in hot climates. A few drops of any acid, vitriol, for example, are used by the workmen in chemical works to improve the water in warm weather.

Alkalies cause water to appear soft. Beer which is called hard is acid, and becomes soft by adding soda; this is common.

The salts of lime seem to be the only salts which do not easily render water disagreeable.

I may conclude this paper with a short summary of what I have said about water and air.

Summary.—1. That the pollution of air in crowded rooms is really owing to organic matter, not merely carbonic acid.

2. That this may be collected from the lungs or breath, and from crowded rooms indifferently.

3. That it is capable of decomposition, and becomes attached to bodies in an apartment, where it probably decomposes, especially when moisture assists it.

4. That this matter has a strong animal smell, first of perspiration, and when burnt, of compounds of protein, and that its power of supporting the life of animalcules, proves it to contain the usual elements of organized life.

5. Organic matter of dew contains less nitrogen.

6. The slightly alkaline state into which soil is put at certain periods of the year, give it a facility for emitting vapours; whilst all vapours of water from organic matter contain organic matter.

7. Water purifies itself from organic matter in various ways: by forming nitrates, as in sewers, and in the neighbourhood of cesspools and churchyards, under streets, in manured grounds, and other repositories of organic animal matter.

8. This may be done in a laboratory on a small scale, where animal matter, by means of a sand-filter, may be converted into nitric acid.

9. In the larger operations of nature the carbon also is oxidized.

10. Sulphuretted hydrogen is also oxidized on a small scale by a filter, being converted into sulphuric acid.

11. A filter therefore, as an oxidizing agent, acts in proportion to its cubic contents.

12. Water falling on the surface of the ground gets rapidly saturated with organic matter; but in passing through the soil gets filtered and the matter oxidized, making the porous soil and the air the great agents of purification in a country; whilst drainage will act by removing organic impurity as well as mere water.

13. All wells near houses and all wells in towns contain nitrates, which may be easily traced to sewers or accumulations and outlets of refuse.

14. The alkaline salts of towns increase the vapidness of water. They abound in river-water which receives the refuse of towns, and cannot be filtered out. The difference between the hardness of water and the amount of water per gallon gives a measure of impurity, as it indicates other than the lime salts, whilst the lime salts affect least the taste of the water.

15. A slight acidity removes vapidness, and produces a perception of coolness in the mouth.

16. Water can never stand long with advantage, unless on a very large scale, and should be used when collected or as soon as filtered.

Eighth Report of a Committee, consisting of H. E. Strickland, *Esq.*, Prof. Daubeny, Prof. Henslow, *and* Prof. Lindley, *appointed to continue their Experiments on the Growth and Vitality of Seeds.*

A portion of all the kinds of seeds collected in 1845 has been sown this year, together with those of a few additional genera collected in 1847.

The results will be seen by reference to the following Table:—

Name and Date when gathered.	No. sown.	No. of Seeds of each Species which vegetated at			Time of vegetating in days at			Remarks.
		Oxford.	Hitcham.	Chiswick.	Oxford.	Hitcham.	Chiswick.	
1845.								
1. Ailanthus glandulosa	50	......	....	3	......	....	32	
2. Alnus glutinosa	150							
3. Alonsoa incisa	100	......	....	5				
4. Beta vulgaris	75	74	33	48	8	10	13	
5. Browallia elata	50	......	....	6				
6. Chrysanthemum coronarium	150	75	29	18	12	13	13	
7. Cytisus albus	100	14	6	4	......	42		
8. Eccremocarpus scaber	100	......	....	3				
9. Fagus sylvatica	100							
10. Fumaria spicata	100	......	....	5				
11. Gaillardia aristata	100							
12. Gleditschia triacanthos	20							
13. Iris, sp.	25	......	....	4	......	....	32	
14. Knautia orientalis	50							
15. Lopezia racemosa	150	132	38	98	10	9	13	
16. Lymnanthes Douglasii	50							
17. Petunia odorata	150							
18. Schizopetalon Walkeri	50	14	4	12	10	13		
19. Secale Cereale	200	......	4	......	......	11		
20. Spartium Scoparium	200	......	6	32	......	35		
21. Tagetes lucida	150	......	....	5				
22. Verbena Aubletia	100							
23. Viscaria oculata	150	17	1	4	......	28		
24. Xeranthemum annuum	100							
25. Zea Mays	100	34	69	24	8	9	13	
26. Zinnia grandiflora	100	......	....	2				
1847.								
27. Cardiospermum Halicacabum	25	20	17	22	......	14	13	
28. Cerastium perfoliatum	100	3	1	10	......	7		
29. Chænostoma polyantha	100	......	....	5				

Miss Molesworth, of Cobham, Surrey, has contributed about fifty small packets of seeds gathered in the years 1842, 1844, 1845 and 1846, which have been sown at Oxford; the results of which are registered in the annexed Table.

Name and Date when gathered.	No. sown.	No. vegetated.	Name and Date when gathered.	No. sown.	No. vegetated.
1842.			1845.		
1. Delphinium, sp.	200	1	27. Æthionema saxatile	100	15
1844.			1846.		
2. Isatis tinctoria	100	15	28. Lathyrus annuus	25	21
3. Tagetes patula	200		29. Zinnia elegans	200	
4. Vicia lutea.	100	91	30. Brassica orientalis	20	
5. Delphinium intermedium	50		31. Linum perenne	100	16
6. Calandrinia grandiflora	80		32. Silene pendula	200	41
7. Allium senescens	60	3	33. Calendula officinalis	200	53
8. Kitaibelia vitifolia	200	23	34. Onopordon Acanthium	80	
1845.			35. Chenopodium Botrys	100	
9. Arabis hirsuta	200	36	36. Lavatera trimestris	100	50
10. Tagetes patula	200	20	37. Arnopogon Dalechampii	30	10
11. Plantago cynops	100		38. Nemophila atomaria	200	62
12. Scandix brachycarpa	150	95	39. Amsinckia angustifolia	100	3
13. Silene Armeria alba	100	31	40. Tropæolum peregrinum	30	15
14. Linaria bipartita	100	6	41. Coreopsis Drummondi	200	
15. Centrophyllum tauricum	25	11	42. Momordica Elaterium	8	
16. Tragopogon porrifolium	100	32	43. Althæa cannabina	30	
17. Androsace macrocarpa	100		44. Calendula maritima	100	26
18. Lasthenia glabrata	100	53	45. Scrophularia vernalis	100	
19. Iberis umbellata	100	11	46. Stevia purpurea	60	
20. Œnothera, sp.	100		47. Eucharidium concinnum	100	
21. Linaria Spartea	100	3	48. Œnothera tenella	100	1
22. Borkhausia fœtida	100	35	49. Sisyrinchium burmudianum	100	1
23. Lathyrus sativus	6	6	50. Nepeta citriodora	100	3
24. Argemone grandiflora	150		51. Silene quadridentata	100	31
25. Vicia grandiflora	25	18	52. Picris echioides	100	73
26. Antirrhinum calycinum	25	9			

A few beans gathered in 1792, from Professor Lindley, were also sown, but none of them vegetated.

The depôt at Oxford now contains seeds of no less than 209 genera, which constitute 56 natural families.

It has now become difficult for persons to procure annually in one locality the seeds of genera which represent additional natural families. We consequently beg again to solicit the assistance of persons interested in the subject; and in order that such persons may readily see whether any kinds that may be obtainable by them would be available for the continuation of these experiments, we subjoin a list of the natural families and genera of which we already possess seeds.

1. Amarantaceæ.
    1. Amarantus.
2. Amaryllidaceæ.
    2. Alstrœmeria.
3. Amentaceæ.
    3. Alnus.
    4. Betula.
    5. Carpinus.
    6. Fagus.
    7. Quercus.
4. Artocarpaceæ.
    8. Morus.
5. Asphodelaceæ.
    9. Allium.
    10. Asparagus.
    11. Asphodelus.

6. Balsamaceæ.
   12. Impatiens.
7. Bignoniaceæ.
   13. Catalpa.
   14. Eccremocarpus.
8. Boraginaceæ.
   15. Cerinthe.
   16. Cynoglossum.
   17. Echium.
9. Campanulaceæ.
   18. Campanula.
10. Capparidaceæ.
   19. Cleome.
11. Caryophyllaceæ.
   20. Buffonia.
   21. Dianthus.
   22. Gypsophila.
   23. Saponaria.
   24. Silene.
   25. Viscaria.
12. Celastraceæ.
   26. Ilex.
13. Chenopodiaceæ.
   27. Beta.
   28. Chenopodium.
14. Cobæaceæ.
   29. Cobæa.
15. Compositæ.
   30. Ageratum.
   31. Ammobium.
   32. Arctium.
   33. Arnopogon.
   34. Aster.
   35. Bidens.
   36. Barkhausia.
   37. Buphthalmum.
   38. Calendula.
   39. Callichroa.
   40. Callistemma.
   41. Carthamus.
   42. Catananche.
   43. Centaurea.
   44. Chrysanthemum.
   45. Cichorium.
   46. Cladanthus.
   47. Cnicus.
   48. Coreopsis.
   49. Galinsoga.
   50. Gaillardia.
   51. Helenium.
   52. Helianthus.
   53. Kaulfussia.
   54. Knautia.
   55. Lactuca.
   56. Lasthenia.
   57. Madia.
   58. Oxyura.
   59. Rhagadiolus.
   60. Rudbeckia.
   61. Sanvitalia.
   62. Scorzonera.
   63. Sphenogyne.
   64. Stenactis.
   65. Tagetes.
   66. Tragopogon.
   67. Xeranthemum.
   68. Zinnia.
16. Coniferæ.
   69. Juniperus.
17. Convolvulaceæ.
   70. Convolvulus.
18. Cruciferæ.
   71. Biscutella.
   72. Brassica.
   73. Bunias.
   74. Crambe.
   75. Erysimum.
   76. Heliophila.
   77. Hesperis.
   78. Iberis.
   79. Koniga.
   80. Lepidium.
   81. Lunaria.
   82. Malcolmia.
   83. Mathiola.
   84. Schizopetalon.
   85. Vesicaria.
19. Cucurbitaceæ.
   86. Bryonia.
   87. Cucurbita.
   88. Momordica.
20. Dipsaceæ.
   89. Dipsacus.
21. Euphorbiaceæ.
   90. Euphorbia.
   91. Ricinus.
22. Ficoideæ.
   92. Mesembryanthemum.
   93. Tetragonia.
23. Gramineæ.
   94. Avena.
   95. Hordeum.
   96. Phalaris.
   97. Secale.
   98. Triticum.
   99. Zea.
24. Hydrophyllaceæ.
   100. Eutoca.
   101. Phacelia.

25. Hypericaceæ.
102. Hypericum.
26. Iridaceæ.
103. Gladiolus.
104. Iris.
105. Tigridia.
27. Labiaceæ.
106. Betonica.
107. Elsholtzia.
108. Leonurus.
109. Nepeta.
28. Leguminosæ.
110. Acacia.
111. Cercis.
112. Cytisus.
113. Dolichos.
114. Faba.
115. Gleditschia.
116. Lathyrus.
117. Lupinus.
118. Medicago.
119. Melilotus.
120. Orobus.
121. Phaseolus.
122. Pisum.
123. Psoralea.
124. Scorpiurus.
125. Spartium.
126. Tetragonolobus.
127. Trifolium.
128. Trigonella.
129. Ulex.
130. Vicia.
29. Linaceæ.
131. Linum.
30. Lithraceæ.
132. Cuphea.
31. Loasaceæ.
133. Bartonia.
134. Loasa.
32. Lymnanthaceæ.
135. Lymnanthes.
33. Magnoliaceæ.
136. Magnolia.
137. Liriodendron.
34. Malvaceæ.
138. Gossypium.
139. Malope.
140. Malva.
35. Nyctaginaceæ.
141. Mirabilis.
36. Onagraceæ.
142. Eucharidium.
143. Godetia.
144. Lopezia.
37. Palmaceæ.
145. Phœnix.
38. Papaveraceæ.
146. Argemone.
147. Eschscholtzia.
148. Glaucium.
149. Papaver.
39. Phytolaceæ.
150. Phytolacca.
40. Plantagineæ.
151. Plantago.
41. Polemoniaceæ.
152. Collomia.
153. Gilia.
154. Leptosiphon.
155. Polemonium.
42. Polygonaceæ.
156. Polygonum.
157. Rumex.
43. Portulaceæ.
158. Calandrinia.
159. Talinum.
44. Primulaceæ.
160. Anagallis.
45. Ranunculaceæ.
161. Aconitum.
162. Adonis.
163. Anemone.
164. Helleborus.
165. Nigella.
166. Pæonia.
167. Ranunculus.
168. Thalictrum.
46. Rosaceæ.
169. Cotoneaster.
170. Cratægus.
171. Potentilla.
47. Scrophulariaceæ.
172. Antirrhinum.
173. Browallia.
174. Collinsia.
175. Digitalis.
176. Linaria.
177. Schizanthus.
178. Veronica.
48. Sesameæ.
179. Martynia.
49. Solanaceæ.
180. Alonsoa.
181. Capsicum.
182. Datura.
183. Hyoscyamus.
184. Nicandra.
185. Nolana.
186. Petunia

187. Solanum.
188. Verbascum.
50. TEREBINTHACEÆ.
189. Ailantus.
51. TROPÆOLACEÆ.
190. Tropæolum.
52. UMBELLACEÆ.
191. Æthusa.
192. Angelica.
193. Bupleurum.
194. Carum.
195. Conium.
196. Daucus.
197. Fœniculum.
198. Heracleum.
199. Ligusticum.
200. Œnanthe.
201. Pastinaca.
202. Petroselinum.
203. Sium.
204. Smyrnium.
53. URTICACEÆ.
205. Cannabis.
54. VALERIANACEÆ.
206. Valeriana.
55. VERBENACEÆ.
207. Hebenstreitia.
208. Verbena.
56. VIOLACEÆ.
209. Viola.

Contributions of additional seeds addressed to W. H. Baxter, Botanic Garden, Oxford, will be attended to, and put up in the usual form for experiment.

Oxford, August 2nd, 1848.

Fifth Report on Atmospheric Waves. *By* W. R. BIRT.

IN completing the series of Reports on Atmospheric Waves, a subject which has occupied my attention under the auspices of the Association during the last five years, it will be desirable so to arrange the present report that those points may be prominently exhibited in which any progress has been made towards the illustration of the desiderata mentioned in my report of 1846, pages 162 to 164. These desiderata have reference to the general subject under two aspects,—that relative to the individual waves, contemplating them either as atmospheric waves, properly so called, or as a certain arrangement of aërial currents giving rise to, and intimately connected with, certain barometric phænomena, the details of which will be found in the same report, page 132 to 162; and that relative to the effects either of these waves or currents as exhibited in certain barometric phænomena, known more particularly as the "symmetrical curve of November," or of other barometric curves possessing certain features which may be distinctly recognized at different stations and traced over extensive tracts of the earth's surface. The object of the present report will consequently be not so much to carry on the investigation (the course pursued in former years) as to concentrate our present knowledge of the subject, and to indicate still more distinctly the blank that yet remains to be filled in order to complete our inquiries into these interesting atmospheric movements.

These objects will probably be best attained by bringing together, in the first place, all the information we possess relative to the individual waves, those already determined and placed on record in our former reports, and those which may have been brought to light since, either from an extended discussion of the observations in our possession at the last meeting of the Association, or from others received during the period that has elapsed since that meeting to the present time; secondly, by determining, so far as the observations in our possession will enable us to do, the barometric type for November, especially the period of the symmetrical curve, as illustrative of

that portion of the desiderata having reference to the *seasonal barometric types*; and thirdly, by noticing any results that may have been obtained during the past year of a character not contemplated or but slightly indicated in our former reports, and which have more particularly originated in the observations of the last return of the November curve.

Table I. exhibits the waves already recognized with references to the reports in which their elements, &c. are given in detail.

The waves designated Nos. 1 and 2 in this table passed over Western Europe during the early part of November 1842. In reporting progress at the last Meeting of the Association, I stated that an examination of the observations made during the first eight days of November over an area extending from Ireland to St. Petersburgh and Geneva, appeared upon the hypotheses either of waves or of parallel currents, fully capable of explaining all the barometric movements during those eight days (Report, 1847, p. 370). In the remarks which immediately follow, this explanation will form a prominent feature, as the variations of pressure during the period just referred to will be traced, especially over Western Europe, and will receive considerable elucidation from observations made at Alten in Finmark, with which I have been kindly furnished by Dr. Lee.

In the former reports which I have had the honour to present to the Association, I have very briefly glanced at two important points connected with these waves, the great extent of surface which they cover, and the opposite barometric phænomena produced by the transits of slopes of an opposite character. In my report for 1846, p. 163, when enunciating the desiderata that then presented themselves, allusion was made to the *direction of the crest*; and there appeared to be some difficulty in finding a point on the earth's surface in reference to which we could positively pronounce that a crest—which clearly existed in a certain direction, in another locality not very far removed from it—had so completely thinned off, and become so distinctly terminated in a longitudinal direction as to exert no influence on the barometer. Such phænomena are not exhibited in the British Islands, and it is likely they are but seldom met with in Central Europe. We must, as remarked on a former occasion, extend our area of examination ere we can obtain phænomena that will enable us distinctly to say that a wave existing in one locality does not exist, or in any way make itself felt in another.

The area of examination having reference to the discussion of the barometric and anemonal phænomena during Nov. 1842, which forms the second part of my report, 1846, pp. 132 to 162, is principally confined to the British Islands; there are two stations forming the eastern limits of this area, which, with regard to Great Britain and Ireland, may be considered as outliers; they however enable us to carry forward our investigation by tracing onwards towards the north-east and east those barometric movements the nature of which the proximity of the British stations has greatly contributed clearly to define, so that they can be readily recognized at stations considerably removed from each other: these stations are Christiania and Paris. By combining with this discussion observations at St. Petersburgh and Geneva our area is still more enlarged, and we are enabled to form a much more accurate notion of the real extent of the waves and of the phænomena resulting from them. By still further enlarging our area of examination, our knowledge must necessarily become more defined and our conceptions more distinct; we shall be prepared to seize on relations which at first may not be apparent, owing particularly to the decided want of similarity between the phænomena

TABLE I.—Elements of Waves ascertained by the author previous to the Meeting of the Association at Oxford in 1847*.

Designation	Period during which the wave was observed traversing the area of observation.	Longitudinal direction of the crest.	Mean Barometric altitude of Crest.	Transverse direction or lines of augmentation or diminution of pressure: Anterior slope or augmentation of pressure in advance of crest			Mean Barometric altitude of anterior trough	Posterior slope or diminution of pressure following crest			Mean Barometric altitude of posterior trough.	Winds forming the parallel currents		Extreme observed points of the transits of crests	Amplitude.		Velocity miles per hour	References.
				Epoch.	Direction.	Value		Epoch	Direction	Value.		Ant slope augmentation of pressure in advance	Post slope diminution of pressure following		Time	Miles		
1	1841. March 18 to 19	S.S.W. to N.N.E.	30·016				29·871				29·975			Mar. 18. Greenwich „ 19. Munich.	h 24			Report, 1845, p. 118
2	1841. March 19	W.N.W. to E.S.E.	30·304															Report, 1845, p. 118.
3	1841. March 19	S.S.W. to N.N.E.	30·304															Report, 1845, p. 118
4	1841 March 20 to 23	N.W. to S.E.	30·057				29·983				29·875			Mar. 21. Greenwich „ 22. Prague.	40			Report, 1845, p 119.
5	1841. March 24	W.N.W. to E.S.E.	30·667															Report, 1845, p. 118
7	1841. March 26 to April 2	S.S.W. to N.N.E.	30·153				29·900				29·718			Mar. 30. Greenwich „ 31. Munich	152			Report, 1845, p 119.
6	1841. March 28	W.N.W. to E.S.E.	30·275															Report, 1845, p 118
8	1841. April 1	N.W. to S.E.	30·095															Report, 1845, p 118
No 1	1842. Nov. 1 to 7	Nov 1 Belfast to Paris	30·290	Nov 1.	Belfast to Christiania	·55		Nov 3	Christiania to Paris	·58		N.W.	S.E.	Nov. 1. Paris „ 5 St. Petersburgh.				Report, 1846, pp 161, 167
No. 2 }	1842 Nov. 1 to 11	Nov. 5. Cork to Orkneys	30·335	Nov. 5.	Belfast to Paris	·80		Nov 9	Paris to Orkneys	·96	29·050	N.E.	S.W.	Nov. 5. Belfast „ 9. Paris				Report, 1846, pp. 161, 167.
A°		Nov. 8. Scilly to Bardsey		Nov 8.	Sth. Bishop to St. Catherine's Pnt.			Nov 9	Munich to Bardsey	·87	29·408†				60	1856	31	Report, 1845, pp. 126, 127
A¹	1842. Nov. 7 to 9			Nov. 7	Glasgow to St. Catherine's Pnt			Nov 9	Geneva to Brussels									Report, 1844, p. 270 (2) „ 1845, pp. 126, 127
A²	1842. Nov. 9 to 10			Nov. 10.	Dublin to Bardsey										36			Report, 1845, p. 127
No 3 }	1842 Nov. 7 to 12	Nov 10. Belfast to Paris	29·560	Nov. 10	London to Christiania	·40		Nov 11	Christiania to Cork	·57		N.W.	S.E.	Nov. 10. Paris „ 12. St. Petersburgh				Report, 1846, pp. 161, 168
B°		Nov. 10 Dublin to Geneva		Nov. 9	Scilly to Longstone	·11		Nov. 10	Longstone to Scilly	·35					102	2600	25	Report, 1845, pp 124 to 128.
B¹	1842. Nov. 9 to 10			Nov. 10.	Bardsey to Longstone	·09										341	25	Report, 1844, pp. 271 to 277 „ 1845, p. 127.
No 5	1842. Nov. 12 to 16	Nov. 14. Belfast to London	29·960	Nov. 13.	Paris to Christiania	·59		Nov. 15	Orkneys to Cork	·64		N.W.	S.E.	Nov. 13 Paris „ 15. Orkneys.				Report, 1846, pp 162, 168
No 4	1842. Nov. 16 to 19		30·520	Nov. 16	Orkneys to Paris	·72		Nov 18.	London to Orkneys	·35		N.E.	S.W.	Nov. 16. Orkneys „ 19. St. Petersburgh				Report, 1846, pp. 161, 168
No 7	1842 Nov. 17 to 19		30·510	Nov. 17.	Belfast to Christiania	·57							S.E.	Nov. 17. Belfast				Report, 1846, p 162
No 9	1842 Nov. 19 to 20		29·960										S.E.	Nov. 20. Orkneys				Report, 1846, p. 162.
No 6	1842. Nov 20 to 24	Nov. 22. Cork to Orkneys	29·590	Nov. 22	Cork to Paris	·15		Nov 24	Paris to Cork	·48		N.E.	S.W.	Nov. 22 Cork „ 24. Paris.				Report, 1846, p 161
No 11	1842. Nov. 21 to 22		29·950	Nov. 21.	Belfast to Christiania	·41						N.W.	S.E.	Nov. 21. Belfast				Report, 1846, p 162
No. 13	1842 Nov. 23 to 24		29·620					Nov 21	Christiania to Cork	1·12				Nov. 21. Christiania				Report, 1846, p. 162
I	1846 Nov 2 to 17	Stornoway to Arbroath	30·660						Arbroath to Galway		30·190							Report, 1847, pp 358, 360.
II.	1846 Nov 4							Nov. 1	Ramsgate to Stornoway Jersey to Limerick	·49								Report, 1847, pp 358, 364.
III.	1846. Nov 4 to 5	Nov. 4. Jersey to Limerick																Report, 1847, p. 358
III*.	1846. Nov 6 to 9		30·352	Nov 6.	From the S.W. towards Arbroath													Report, 1847, pp 359, 363
II*.	1846. Nov. 11			Nov. 11.	Stornoway to Ramsgate	·29												Report, 1847, p. 361.

TABLE VII.—Elements of waves as determined from the discussion of observations over the larger area included by Cork and Lougan, Alten and Geneva.

Designation	Period	Longitudinal direction of the crest	Mean Barometric altitude of Crest	Ant. Epoch	Ant. Direction	Value	Mean Barometric altitude of anterior trough	Post. Epoch	Post. Direction	Value	Mean Barometric altitude of posterior trough	Ant slope	Post slope	Extreme observed points of the transits of crests	Time	Miles	Velocity	References
a.	1842. Nov. 1 to 9	W.S.W. to E.N.E.	30·280	Nov. 3.	Alten to Lougan	1·580	29·038	Nov. 9.	Lougan to Alten	·768	29·341			Nov. 3. Alten „ 9. Lougan.	288	3181	11	
No. 2 }	1842. Nov. 1 to 11	Nov. 5. Cork to Alten	30·330	Nov. 5.	Belfast to Geneva	·760	29·790	Nov. 9	Geneva to Belfast	·670	29·110	N.E.	S.W.	Nov. 5. Belfast „ 9. Geneva.		1577	8 5‡	
A° No 1	1842. Nov. 1 to 7	Nov. 1. Belfast to Geneva	30·300	Nov. 1.	Geneva to St Petersburgh	·889	29·419	Nov. 5.	St Petersburgh to Geneva	·465	29·786	N.W.	S.E.	Nov. 1. Geneva „ 5 St Petersburgh		2730	14 22	
No. 4	1842. Nov. 16 to 20	Nov. 18. Brussels to Alten	30·520									N.E.	S.W.	Nov. 17. Belfast. „ 19. Munich „ 18. Alten. „ 20 Lougan.				
No. 0	1842. Nov. 1 to 2							Nov. 2.	Alten to Christiania	·190			S.E.					

In connection with these Tables, it may be as well to solicit attention to the *convergence* of the lines indicating the transverse direction or lines of augmentation or diminution of pressure of the north-westerly systems of waves, distinguishing the Scandinavian from that of Central Europe. It would appear that the transverse directions, or those in which the waves advance, are at *right angles*, or nearly so, to tangents appertaining to the general curvilinear directions of the coasts or junction lines of land and water, so that the directions of the waves of Northern Europe more nearly approach the direction of the meridian than those of Central Europe. This appears strongly to indicate the proximity of land and water, as the locality of genesis of atmospheric waves, and is greatly in accordance with the results obtained by Sir John Herschel and the late Professor Daniell, that the oscillation is greatest in such localities. See Report, 1846, p. 147.

* Previous to my undertaking the present inquiry Sir John Herschel had determined the elements of two waves, one which traversed Western Europe in September 1836, the other in December 1837. The longitudinal direction of the crest of the first was S.S.W.—N.N.E., transverse direction W.N.W.—E.S.E.; semi-amplitude in miles 540, in time 26 hours; velocity 21 miles per hour; barometric depth 0·2 inch (Report, 1843, p. 70). The longitudinal direction of the crest of the wave of December 1837 was 10° W. of S.—10° E. of N.; transverse direction 10° N. of W.—10° S. of E.; velocity 18·62 miles per hour (Report, 1843, p. 77).

† This trough was situated on the anterior slope of No. 3 or B°, which occasioned the readings to be lower in the neighbourhood of the Orkneys.

‡ The velocity of this wave appears to have increased to about 26 miles per hour as it passed from the coasts of Wales towards the centre of Europe.

presented at distant and especially at *extreme* stations, and to distinguish between those effects, which, although to a certain extent contemporaneous and similar, may be referred to different sources of production.

By including in the discussion of the observations of 1842 observations at Alten in Finmark and at Lougan in Russia, the former being situated north lat. 69° 50′, east long. 23°, and the latter north lat. 48° 35′, east long. 39° 21′, our area of examination is extended from Ireland to the eastern borders of Europe, and from Geneva to the northern extremity of the same continent; it will consequently embrace 47 degrees of longitude and 23 of latitude.

The table of barometric observations, November 1842, forming the groundwork of the discussion, will be found in the volume for 1846, p. 141; the readings at St. Petersburgh during the same days at noon, are recorded at p. 167 of the same volume; and the following table includes readings for the same period at Alten, Lougan and Geneva.

TABLE II.

Barometric readings at Alten, Lougan and Geneva, Nov. 1 to 26, 1842.

Date.	Alten, 3 P.M.	Lougan, noon.	Geneva, noon.
Nov. 1	30·138	29·312	30·338
2	·601	·300	30·089
3	·589*	·088	29·884
4	·288	·440	·820
5	30·140	·459	·786
6	29·690	·332	·864
7	·416	·769	29·926
8	·596	29·980	30·011
9	·436	30·106	·080
10	·514	30·001	30·056
11	·453	29·810	29·842
12	·607	·785	29·842
13	·586	·623	30·097
14	·134	·613	·100
15	·092	·599	30·084
16	·303	·676	29·863
17	29·641	·689	29·891
18	30·110	·610	30·334
19	30·066	·609	·529
20	29·825	·885	30·098
21	·658	·638	29·707
22	·674	·445	·731
23	·539	·294	·865
24	·570	·785	·549
25	·715	·738	·364
26	29·880	29·791	29·271

It will be readily seen from an inspection of this table that the observa-

* Max. on the 3rd at 9 A.M. 30·618.

tions from the two southern stations tolerably agree, although the readings at Geneva are higher than those at Lougan, especially during the first eight days; but there is a marked difference between them and those at Alten. The first point that strikes attention in comparing these readings with those in the tables, to which allusion has been made, is the earlier occurrence at Alten, namely on the 3rd, of the maximum which characterizes the first portion of the month, and which is very distinct at all the stations, except Paris, Geneva and Lougan. The observations at Christiania more nearly agree with those at Alten in this respect, the maximum occurring on the 4th; and from this it would appear that the *pressure proceeded from the north, and in a direction in which we do not usually observe the progression of the barometric maxima and minima.* The principal epoch of the maximum for the majority of the stations is the 5th, and this maximum has been referred to the wave designated "Crest No. 2" in the discussion of Mr. Brown's observations, and "A°" in my second report (Report, 1845, p. 126). The direction of this maximum has been well determined on the 5th, namely from Cork past Belfast to the Orkneys (Report, 1846, p. 144). We find at Alten on the 5th a decided rise of nearly ·2 inch on the deep precipitous fall from the 3rd to the 7th, and this would indicate the continuation of the crest from Cork to Alten. From these considerations it is evident that the maximum of the 3rd at Alten must have been due to an entirely different wave from any we have already noticed. The curve that most approaches Alten in the *rise* at the commencement of the month is that of St. Petersburgh; and it is worthy of remark, that the essential features of this rise, and the check it experienced before the transit of the maximum, are transmitted to St. Petersburgh a day later than they were observed at Alten. In fact the three northern stations, Alten, St. Petersburgh and Christiania, participate in this rise, the subsequent fall being considerably modified at Christiania and St. Petersburgh by the transit of crest No. 1.

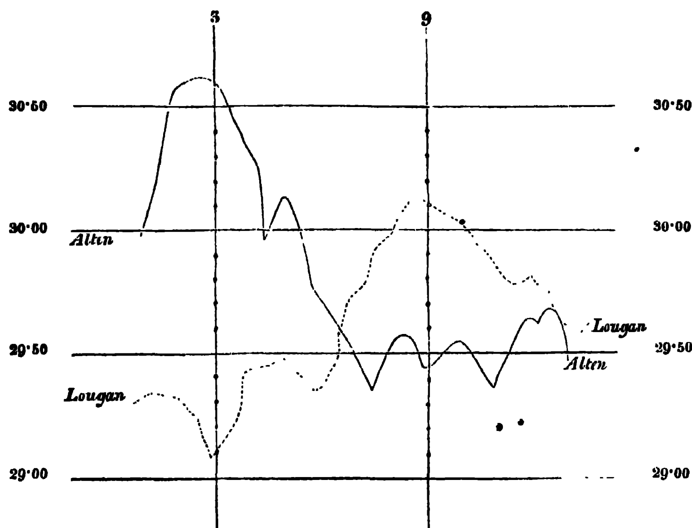
The barometric rise at the commencement of the month in the north of Europe, to which allusion has just been made, strongly indicates the advancing slope of a wave which *did not affect the barometer in Central Europe*; and this wave being peculiar to the northern part of Europe, and stretching over the Scandinavian peninsula, may probably, and with some propriety, be designated as a member of a system of Scandinavian waves. We shall therefore characterize it in the future parts of this discussion by the symbol *a*, restricting this character to these northern waves. It does not appear to have extended longitudinally much beyond Christiania to the south-west, for we do not find that decided rise of the barometer, even at the Orkneys, which characterizes northern Europe. We have consequently a distinct termination of the crest in a *longitudinal direction*, the locality of which may be indicated by a line passing towards the south-east between the Orkneys and Christiania.

We have already briefly referred (Report, 1847, p. 369) to the opposite barometric movements in certain localities, arising from the transit of opposite slopes, either of the same wave or of successive waves of the same system, and these phænomena, which are very distinctly marked in the instance given, furnish us with an explanation of similar phænomena in other localities. The curves of Alten and Lougan (fig. 1) present similar phænomena to those of Geneva and St. Petersburgh; the movements are opposite, and in this respect more decided, for we have *two* periods of opposite movements at Alten and Lougan. We have consequently the half breadth of this Scandinavian wave given from Alten to Lougan, 1592 miles; first, when the

anterior slope extended from Alten to Lougan, the crest transiting Alten, while the anterior trough passed Lougan; and second, when the posterior

Fig. 1.

November 1842.



Opposite barometric curves at Alten and Lougan.

Points of opposition, Nov. 3, maximum, Alten.
,, ,, Nov. 3, minimum, Lougan.
,, ,, Nov. 9, maximum, Lougan.
,, ,, Nov. 9, minimum, Alten (?)

slope covered the area, the crest having arrived at Lougan, at which time in all probability the posterior trough was vertically over Alten. The decided opposition of the curves also enables us to determine with considerable precision all the elements of the wave. It appears highly probable that the two subordinate maxima of the 8th and 10th in the Alten curve resulted from waves in the trough of this Scandinavian wave, and that its true minimum occurred on the 9th; this would give nearly equal intervals for the transmission of the anterior slope and crest from Alten to Lougan, the posterior slope on the 9th stretching from Lougan to Alten. Upon this supposition we have the following elements:—

Of the great Scandinavian Wave a.

Designation, *a*.
Direction of crest W.S.W.——E.N.E.
Extreme points, anterior slope, Lougan, Alten.
Semi-amplitude from anterior slope, 1592 miles.
Extreme points, posterior slope, Alten, Lougan.
Semi-amplitude from posterior slope, 1592 miles.
Epoch of anterior trough, Lougan, Nov. 3.
,, crest Alten, ,, 3.
Lougan, ,, 9.
posterior trough, Alten, 9.

Time of transit of crest from Alten to Lougan, 144 hours.
Amplitude of wave in time, 288 hours.
„ „ „ miles, 3184 miles.
Velocity of wave, 11 miles per hour.

We have also the following determinations of the altitude of this wave:—

	d	h
The crest passed Alten............Nov.	2	21
The posterior trough ....Nov.	8	21 ?
Interval...........................	6	0

Altitude of crest at Alten	30·618
„ posterior trough	29·341 ?
„ wave at Alten............	1·277
Altitude of crest at Lougan	30·109
„ anterior trough	29·038
„ wave at Lougan	1·071
Nov. 2, 21, crest at Alten............	30·618
„ 2, 20, anterior trough, Lougan....	29·038
Altitude of wave from anterior trough..	1·580
Nov. 8, 22, crest at Lougan	30·109
„ 8, 21, posterior trough, Alten	29·341 ?
Altitude of wave from posterior trough .	·768

St. Petersburgh, which is situated nearly midway between Alten and Lougan, and not far removed from the line cutting the wave transversely, affords us an excellent mean of testing the accuracy of the views advanced relative to the great Scandinavian wave. The following table exhibits the progression of the crest across Lapland and Russia, and the distribution of pressure on each side as it transits.

Table III.

Barometric altitudes and differences arising from the transit of the Scandinavian wave across Lapland and Russia in 1842.

November 3 to 9.

Date.	Alten.	Diff.	St. Petersburgh.	Diff.	Lougan.
Nov. 3.	30·589M	·317	30·272	1·134	29·138
4.	·288M	·100	·188	·748	·440
5.	30·140	·089	·229M	·820	·409
6.	29·690	·466	30·156M	·784	·372
7.	·416	·517	29·933M	·159	29·774
8.	·596	·399	·995	·030	30·025M
9.	·436	·470	·906	·189	·095M

Alten to St. Petersburgh .... 740 miles
St. Petersburgh to Lougan ...... 860 „
The readings at Alten are at 3 P.M.
„ „ St. Petersburgh, 3 P.M.
„ „ Lougan, 4 P.M.

It may probably assist our conception of the transit of this wave if the position of the crest for each day is particularized as under:—

Nov. 3. Crest passing Alten. This crest evidently possessed considerable breadth, for we find only a diminution of 0·317 inch pressure from Alten to St. Petersburgh, 740 miles; from St. Petersburgh to Lougan, 860 miles, the dip is very much greater, 1·134 inch above three times.

Nov. 4. Crest between Alten and St. Petersburgh. In consequence of the broad crest these stations are nearly on a level, the dip from St. Petersburgh to Lougan still very considerable, 0·748 inch.

Nov. 5. St. Petersburgh, the highest point; the crest not yet arrived; dip from St. Petersburgh to Alten, 0·089 inch; from St. Petersburgh to Lougan, 0·820 inch.

Nov. 6. The crest rapidly approaching St. Petersburgh, which it transits most probably this day; the anterior slope still presents considerable steepness; dip from St. Petersburgh to Lougan, 0·784 inch; Alten is only 0·318 inch above Lougan.

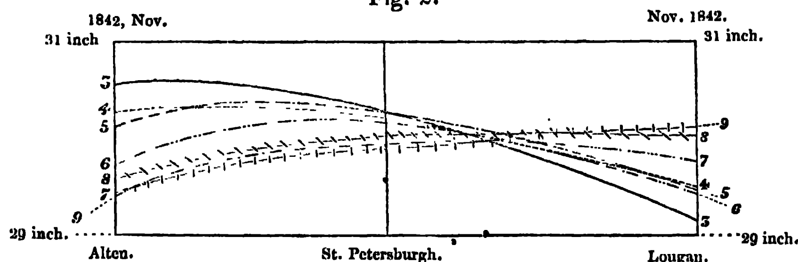
Nov. 7. The crest has now clearly passed St. Petersburgh; this station is slightly raised above Lougan, but the dip to Alten has become considerable, 0·517 inch.

Nov. 8. The direction of the dip is reversed, being from Lougan to Alten increasing.

These phænomena are rendered very apparent to the eye in the diagram, fig. 2.

The great Scandinavian wave presents very distinctly at Alten the well-known characteristic of the north-westerly system of waves, namely, that of a considerable and precipitous fall as the posterior slope passes; this fall is only interrupted by the crest of wave No. 2 on the 5th.

Fig. 2.



Distribution of pressure on the line from Alten to Lougan, from Nov. 3, the epoch of the transit of the Scandinavian wave at Alten; to Nov. 9, the epoch of the transit of the crest at Lougan. Barometric altitudes half the natural scale.

In addition to the determination of this large Scandinavian wave, with its elements and phases, the additional observations at Alten, Geneva and Lougan, assist us considerably in more distinctly defining and limiting the waves already brought to light by former discussions. The breadth of the anterior slope of crest No. 1 (Report, 1846, p. 142) is found to extend beyond Christiania, but not so far as Alten, and the rise from Christiania to Alten, of ·36 inch on the 1st of November, clearly indicates the posterior slope of a wave preceding crest No. 1. The anterior slope of crest No. 1 is also more distinctly manifested by the observations at St. Petersburgh and Geneva than by those at Belfast and Christiania, the depression of St. Petersburgh below

Geneva being ·89 inch. We have consequently *two* sections of the anterior slope of crest No. 1, that from Geneva to St. Petersburgh cutting the wave more transversely than the other. These observations also enable us to determine with more precision the longitudinal direction and extent of this crest, for we now trace it from Belfast across the centre of England, through France to Geneva. It appears to have been depressed in France by the anterior trough of crest No. 2.

While we thus have the anterior slope of wave No. 1 covering the northern parts of Central Europe, and being distinctly terminated on a line parallel to its crest, passing through or beyond St. Petersburgh and to the north of Christiania, so that from the crest to this line the pressure diminishes, we have the posterior slope of the preceding wave passing off towards the north-east, as shown by the Alten observations, which exhibit a greater pressure than those at Christiania. We have also, crossing these waves, two anterior slopes, one in Scandinavia and Russia, extending from beyond Alten to the north-west to beyond St. Petersburgh to the south-east. It is this slope that produces a considerable rise in the barometer at Alten, and from this station to St. Petersburgh it measures ·69 inch. This anterior slope is distinctly terminated longitudinally by a line passing between the Orkneys and Christiania. The other anterior slope alluded to is that of the wave designated crest No. 2; it appears to be terminated on this day by its anterior trough in the neighbourhood of Paris. The crest is considerably to the north-west of Great Britain and Ireland.

On the 2nd of November we find the posterior slope of the wave preceding crest No. 1, more distinctly developed at Alten with its proper wind S.E.; we also find the N.W. and S.E. parallel currents fully established from Great Britain and Ireland to Alten, as under:—

Posterior slope of wave-crest No. 0* S.E. at Alten.
Anterior slope of wave-crest No. 1. N.N.W. at Christiania.
Posterior slope of wave-crest No. 1. S.E. Great Britain and Ireland.

The anterior slope of the Scandinavian wave from Alten to St. Petersburgh is very distinctly developed on the 2nd, possessing, although not to so great an extent, the marked diminution of pressure towards its anterior trough which obtains between St. Petersburgh and Lougan on the 3rd.

Nov. 3. The crest of the Scandinavian wave now transits Alten and its anterior trough Lougan, so that we have the whole of European Russia and Scandinavia covered by its anterior slope. The wave-crest No. 1 appears to occupy a position nearly coincident with the line terminating this wave longitudinally; and the wave-crest No. 2, which receives its greatest development in Central Europe, approaches from the north-west, so that the three waves contribute to produce high barometric readings in the north-west of Europe, the area of greatest pressure, as indicated by readings above 30 inches, extending from Alten and St. Petersburgh across the Scandinavian peninsula and Scotland to the north of Ireland.

Nov. 4. The Scandinavian wave rolls onward towards the south-east, depressing the barometer at Alten and raising it at Lougan. The wave-crest No. 2 of Central Europe approaches from the north-west, raising the barometer in Great Britain and Ireland. The wave-crest No. 1, a south-westerly wave, still crosses the Scandinavian peninsula, keeping up the

* This symbol is employed to designate the wave preceding the south-westerly waves determined by the discussion of Mr. Brown's observations. See Report, 1846, pp. 140 to 160.

barometer in that part of Europe; its presence is very distinctly marked, Alten, Christiania and St. Petersburgh being nearly on a level: the order of altitudes is as follows:—

Christiania	30·37
Alten	30·29
St. Petersburgh	30·22

We have consequently the area of greatest pressure approaching the central parts of Europe from the north-west; the Scandinavian wave, which raises the barometer in the north-east, being considerably in advance of that of Central Europe, crest No. 2, which contributes to the rise in the south-west.

Nov. 5. On this day we have the turning-points of the opposite curves, Geneva and St. Petersburgh (see fig. 10, pl. 27, Report, 1847); they clearly indicate the half-span or semi-amplitude of the wave-crest No. 1, the crest being vertically over St. Petersburgh (max.) while the trough transits Geneva (min). The semi-amplitude is consequently 1365 miles, and the velocity of the crest, as determined from the epochs of its passing Geneva and St. Petersburgh, 14·22 miles per hour. This wave appears to have been rather larger than its successor, wave-crest No. 3 or B°, the elements and phases of which are given on p. 124, Report, 1845.

The rise at Alten on this day, on the steep posterior slope of the Scandinavian wave, enables us to extend the line of crest No. 2 from Cork, the extreme south-western station, to Alten, the extreme north-eastern; and the reduced reading at Alten, 30·14, clearly indicates that the greatest swell occurred in Central Europe: the readings along the crest are as follows:—

Cork, 30·32; Belfast, 30·55; Orkneys, 30·52; Alten, 30·14.

From these numbers we learn that the greatest swell occurred in the north-east of Ireland, and that the wave thinned off very considerably towards Alten, being perceptible as a subordinate maximum only. Had not wave-crest No. 2 extended to Alten, the barometric differences between Alten and St. Petersburgh would have been much greater. The crests Nos. 1 and 2 intersected to the north-west of Norway. See Report, 1846, p. 167.

The area of greatest pressure has much the same direction as on the 4th, extending from the south-west of Ireland across Scotland and the Scandinavian peninsula to St. Petersburgh. The greater swell of the wave-crest No. 2 in the neighbourhood of Ireland and Scotland contributes to the high barometric readings in those localities; the intersections of crests Nos. 1 and 2 to the high readings in the southern parts of Norway; and the intersection of the Scandinavian crest *a* with No. 1 to the altitude, as observed at St. Petersburgh. The distribution of the crests is as follows:—

Scandinavian crest *a*	To the west of and approaching St. Petersburgh.
Crest No. 2	Extending from Ireland to Alten.
Crest No. 1	Crossing each of these on a line to the north-east of that terminating the Scandinavian wave longitudinally.

Scandinavia and Russia are now covered partly by the anterior and partly by the posterior slopes of the Scandinavian wave; Northern Central Europe by the posterior slope of crest. No. 1, and Western Europe by the anterior slope of crest No. 2.

The lowest reading on this day, with the exception of Lougan, is Geneva, 29·79, the posterior trough of crest No. 1. It is probable that the troughs

o^r ,nd 2 intersect in the neighbourhood of Geneva; if so, we have for ι. mining the semi-amplitude of crest No. 2, the following data:—

Semi-amplitude....The anterior trough being at Geneva.
The crest at Belfast .... 792 miles.

Nov. 6. While the *anterior* slope of crest No. 2 is most strikingly developed over Western Europe, extending from Belfast to Geneva, the *posterior* slope of the Scandinavian wave, which now transits St. Petersburgh, is also developed from that station to Alten; and between these slopes, and crossing them more or less at right angles, we have crest No. 1 still between Christiania and Alten, so that we have a considerable elevation of the barometer in Great Britain and Ireland, the extremity of the Scandinavian peninsula, and at St. Petersburgh. On each side this ridge of pressure the barometer exhibits lower readings; at Geneva, 29·86; at Alten, 29·69; both at the level of the sea.

The area of greatest pressure has much the same direction as on the 5th, with this exception, the north-eastern extremity makes a greater progress towards the south-east than the south-western. This is precisely a consequence of the waves being situated as the observations indicate. The area of greatest pressure does not result from a single wave-crest, but is due to at least three contemporaneous crests in Northern and Central Europe, two of these having the *same* direction, but one being in advance of the other, and the third crossing these nearly at right angles. As the advanced north-west wave passes off towards the south-east the pressure diminishes in the north-east, thus giving rise to the unequal motion of the two extremities of the area of greatest pressure.

Nov. 7. The barometric movements over western Central Europe are very small; in Northern Europe they are greater. In the first area, Western Central Europe, the crest No. 2 is transiting; this crest thins off towards Northern Europe, and the Scandinavian wave considerably influences the barometer in this the northern area. Barometric falls in Northern Europe, including the Orkneys:—

The Orkneys	·31
Alten	·27
St. Petersburgh	·20
Christiania	·19

While the barometric falls at St. Petersburgh and the Orkneys appear to have resulted from two different causes, two distinct posterior slopes, the fall at Alten appears to have been compounded of these two slopes, viz. that of the Scandinavian wave and that of crest No. 2. The area is thus divided into two sub-areas, Alten, Christiania and the Orkneys falling from crest No. 2, and St. Petersburgh from crest No. 1 and the Scandinavian wave.

During the operation of the causes just alluded to, by which the pressure has been diminished at Christiania and St. Petersburgh, these stations are brought more to a level with Geneva from the approach of crest No. 3. At Alten the barometer has been falling principally from the posteri[illegible] of the Scandinavian wave; a trough now transits Alten, but from [illegible] opposite curves at this station and Lougan it does not appear to be the posterior trough of the Scandinavian wave, which most probably transited on the 9th; it is most likely to be a secondary trough, or rather minimum, produced by the approach of crest No. 1, which probably transited this station on the 8th.

The following table exhibits the distribution of the crests and troughs on this day:—

TABLE IV.

Distribution of Crests and Troughs on November 7, 1842 :-

Phase.	Locality.
Crest No. 1	Between Christiania and Alten, approaching Alten.
Trough between Nos. 1 and 3	North-east of Belfast and Paris.
Crest No. 3	South-west of Great Britain and Ireland.
Crest No. 2	Passing south-east of the Orkneys across Scotland and England.

The general direction of high pressure extends over Ireland, England, the north of France, Holland, Northern Germany, the southern parts of Sweden and Norway, and the central parts of Western Russia. From this ridge or area of high pressure to Alten there is a considerable dip.

Orkneys to Alten........................ ·73
Christiania to Alten .... ·60
St. Petersburgh to Alten .... ·54

It is thus apparent that the area of greatest pressure has gradually approached the south-east, and assumed in its progress a more curvilinear direction than it possessed at the commencement of the month. The locality in which the pressure has been more constantly maintained is the northern part of the British Isles, the southern part of Scandinavia, and Western Russia.

It would appear from the above values of the diminution of pressure to Alten, that the slope from the Orkneys to Alten was an anterior slope of the south-west system, but other considerations, especially the trough between 1 and 3, clearly show that this is not the case ; the depression at Alten results from the posterior slope of the Scandinavian wave, and the altitude at the Orkneys evidently results from the wave-crest No. 2, which passed that station on the 5th.

Nov. 8. At 9 P.M. of the 7th the barometer passed a minimum at Alten, value 29·34, and at 3 P.M. of this day it had risen to 29·60, a maximum. It is very likely that this maximum is crest No. 1. This movement, and the fall from the posterior slope of crest No. 2, brings the northern stations to a greater equality of level.

TABLE V.

Area of greatest pressure, November 8, 1842, slightly above 30 inches :—

South-west.		Central.		North-east.	
Cork	30·01	Belfast	30·04	St. Petersburgh	29·96
Plymouth	30·13	London	30·08	Lougan	29·98
		Bristol	30·07		
		Paris	29·90		
		Geneva	30·01		

Area of the barometric fall which commenced on this day (see Report, 1846, p. 147) :—

Alten .... 29·60
Christiania .... 29·67
Orkneys .... 29·63

The area of greatest pressure (just above 30 inches) extends from Ireland and England across France and Switzerland, and the central portions of Western Russia, having nearly an easterly and westerly direction. In the northern parts of Scotland (the Orkneys), Norway and Lapland, the pressure is about ·4 inch lower.

Nov. 9.	Crest of Scandinavian wave	Lougan......	30·11
	Crest of wave No. 2	Geneva......	30·08
	Crest of wave No. 2	St. Petersburgh	29·92

The passing off of the area of greatest pressure towards the south-east is now most decided; it extends from St. Petersburgh and Lougan towards Geneva. The higher reading at Lougan is clearly due to the crest of the Scandinavian wave, those at St. Petersburgh and Geneva to the crest of No. 2; Paris and the stations to the north-west of it, including Christiania and Alten, all exhibit lower readings, being under the contemporaneous and continuous posterior slopes of the Scandinavian wave and of crest No. 2.

We have some reason to believe that the readings of the 5th, at Belfast and Geneva, assist us materially in determining the semi-amplitude of wave-crest No. 2. The crest now passes Geneva, and from this we may gather that the velocity was about 8·25 miles per hour. In comparing these with the similar elements of wave A°, as deduced from observations at Scilly, Bardsey and Munich on this day, we find the present determination to be less than that recorded in the Report for 1845, p. 127. It would, however, appear that the amplitude 1856 miles is too great, the distance from Bardsey to Munich being 785 miles. This amplitude has been determined from the posterior slope. The observations at Geneva and Belfast enable us to determine the anterior, those at Munich and Bardsey the posterior slope; by combining them we have the amplitude determined from the two slopes.

Anterior slope, Geneva to Belfast ...	792	miles.
Posterior slope, Bardsey to Munich..	785	„
Amplitude of wave	1577	„

The near approximation of the values of the anterior and posterior slopes gives a proportionate confidence in this determination of the amplitude.

By taking the time of transit, Belfast to Munich, we have nearly the same velocity given as from Belfast to Geneva, namely, 8·78 miles per hour. The velocity of this crest or wave appears to have been variable; it clearly passed very slowly over Ireland, the barometer attaining a considerable elevation. On the morning of the 8th we find its direction from the south-west of England, past Norfolk, to the east of Christiania; a line of crest also extends from Scilly past South Bishop and Bardsey, connected probably in some way with A^1. From this time the velocity appears to have increased rapidly; for on the next day, the 9th, we find the crest south-east of Paris, and at 3 P.M. it appears to transit Munich. Its increased velocity appears to have commenced upon its passing the coast of Wales. Taking the amplitude of the posterior slope from Bardsey to Munich = 785 miles, and the time of the passage of the crest over this space = 30 hours (see Report, 1845, p. 126), the increased velocity is about 26 miles per hour.

The altitudes of the anterior and posterior slopes from the Belfast and Geneva observations appear to be as under:—

Nov. 5.	Crest at Belfast..............	30·55
	Anterior trough at Geneva	29·79
	Altitude of wave from anterior trough	·76

Nov. 9. Crest at Geneva .... 30·08
Posterior trough at Belfast ...... 29·41

Altitude of wave from posterior trough ·67

The Bardsey and Munich observations appear to give a higher value for the posterior slope.

The preceding remarks have exclusive reference to the barometric movements over Central and Northern Europe during the first nine days of November. Among the results obtained from combining the Alten observations with those before enumerated, we have the extension of the crest No. 2 to the extreme north of Europe. In like manner it may be expected that the succeeding wave-crest No. 4 would also stretch across the European continent in the same direction, and that the Alten observations would confirm the suggestion published at the end of my third report (Report 1846, p. 372), that this wave stretched to the very north of Europe. On consulting them we find the barometer passed a maximum at 9 P.M. of the 18th, value 30·114. The epoch of this maximum, its value being considerably lower than those of the maxima observed in Central Europe about the same time, and the similarity that exists in this respect to the altitude of wave-crest No. 2 as it passed Alten, the greatest *swell* occurring in Central Europe, tends greatly to identify this maximum with wave-crest No. 4, and that the greatest swell of this wave also occurred in Central Europe.

The following table exhibits the passage of crest No. 4 from Ireland to the eastern borders of Europe during the 17th, 18th, 19th and 20th of November 1842:—

TABLE VI.

Epochs of the transit of Wave-crest No. 4, November 1842.

Stations.	Day.	Hour.
Glasgow	17	Noon*.
Dublin	17	11 P.M.
Greenwich ...	18	10 A.M.
Brussels	18	6 P.M.
Alten	18	9 P.M.
Geneva	19	9 A.M †
Munich	19	9½ A.M †
St Petersburgh	19	10 P.M.
Lougan	20	2 P.M.

Table VII., which is supplemental to Table I. facing page 36, embodies the results of the examination of the barometric movements over the larger area above specified, and includes the elements of the three prominent waves, *a*, A°, and No. 1.

In collecting the results of the examination of these waves over the larger area embraced by the observations at Alten, St. Petersburgh and Lougan,

* The early transit of the maximum at Glasgow appears to have been connected with the south-westerly wave-crest No. 7, which crossed No. 4 at Belfast; this is supported by the observations at Sir Thomas Brisbane's Observatory, Makerstoun.

† As the observations at Geneva are not taken between 9 P.M. and 9 A.M., it is highly probable the maximum occurred earlier, and that there was a longer interval between the times of transit at Geneva and Munich than half an hour.

in connection with those enumerated in former reports, our attention is arrested by the distinctness with which the waves Nos. 1 and 2 are exhibited, and the striking individuality appertaining to the wave *a*, determined in the first instance by only *two* sets of observations, those at Alten and Lougan, from *the opposition of their barometric curves*, and afterwards fully confirmed by the observations at St. Petersburgh. The facility with which we are enabled to trace, during the nine days of examination, the progression of the area of greatest pressure, which results from the presence of the crests of these waves, and the modification of form which this area of greatest pressure undergoes from the different *positions* of waves *a* and No. 2, and also from the different direction as well as position of wave No. 1, such modification of form not being at all recognizable as the effect of any single movement, but clearly resulting from such movements as have by this discussion been brought to light, leads to the conviction that during the first nine days of November 1842, the waves having reference to that period, which are particularized in Table VII., were the only atmospheric waves of *considerable magnitude* that during those days flowed over Europe. We are therefore enabled to specify, as prominent results of this inquiry, two large waves, one about *double the breadth* of the other, coming over from the north-west, the largest extending indefinitely—so far as we can learn from the observations before us—towards the north-east, from a line passing between the Orkneys and Christiania towards the south-east, and covering first with its anterior, and afterwards with its posterior slope the whole of Northern Europe. The smallest wave is traced to a much greater extent longitudinally, Cork and Alten being the extreme stations indicating the presence of its crest: its posterior trough appears to have been contemporaneous and continuous with that of the largest wave; so that while the crest of the largest wave traversed Eastern Europe, the crest of the smallest crossed Central Europe, the trough common to both passing over the British Islands at the same epoch. We are also able, in addition to these waves, to particularize another, having a different direction, its crest extending N.W. to S.E. from Ireland to Switzerland; so that in the course of its progress to the north-east it crosses them : the half breadth of this south-westerly wave, as manifested by its anterior slope, extended from Geneva to or beyond St. Petersburgh. The posterior slope gave a somewhat similar result.

While we are able to indicate the amplitude, altitude, direction, march, and velocity of the atmospheric waves above specified, our knowledge is greatly deficient relative to their longitudinal extent; nor are we able to exhibit on a chart, at any given moment, the line of crest and the bounding troughs of any one of these waves so as to exhibit to the eye the extent of surface it covers in the totality of its existence. That these blanks can be filled with less difficulty than might at first sight be imagined, is evident from the ease with which it is possible to determine the elements of a wave from *two* sets of barometric observations, each at a different station, provided such observations present *opposite* movements. In the case of the south-westerly wave above specified, we have only to find a point as much to the south-west of Geneva as that city is south-west of St. Petersburgh, and we shall again have opposite movements to those at Geneva, provided the locality of genesis of the south-westerly waves is situated still further to the south-west, and that the movements do not receive considerable modification from the influence of the north-westerly waves. The distance between the two extreme points of opposite movements, as referred to the central point, will mark the amplitude of the wave, and these points will be situated in the

bounding troughs, as exhibited on the chart alluded to. How far the conditions above named exist, we are unable to determine in the present state of our knowledge. The elements of the waves already ascertained, indicate, however, the localities from which we may seek to obtain observations that will immediately illustrate these desiderata; and should we not be able to obtain them for the year in question, viz. 1842, observations in future years on the lines of country indicated by the discussion of the observations in 1842, already obtained, may be very available for distinctly marking out the great tracts of country over which the waves extend, and furnishing data from which charts, such as have been alluded to, may be constructed.

The three waves above specified, in consequence of the minute investigation which the observations have undergone, may be considered as exhibiting the nearest approach to accuracy in the determination of their elements; there are, however, other waves succeeding them, which, although not so precisely determined as to their extent, velocity, &c., yet are so clearly placed before us as to warrant the conclusion that the same close discussion of the observations for succeeding days would furnish similar results with regard to them. These waves are particularized in the table as No. 3 or B°, No. 5 and No. 4.

PART II.

Taking a single station in the extended area, to which allusion has been made in the first part of this report, and examining the barometric phænomena exhibited at that station, the result of such an examination has indicated,—first, that the barometric curve is *compounded* of the effects produced by each individual wave as it passes the station in its onward progress; and secondly, that so far as the symmetrical curve is concerned, the essential characters of this symmetrical curve are repeated year after year. The objects of the second branch of our inquiry are, therefore, essentially different from the first—they consist of the seasonal barometric types or curves, such curves being obtained from observations of the barometer at the station selected, without reference to observations at other stations. In my report 1845, pp. 121 to 123, illustrated by plate 3, we have the characteristics of the symmetrical curve for 1842, 1843, and 1844. Further notices of the symmetrical curves for 1845 and 1846 occur in the reports for 1846 (pp. 130 to 132) and 1847. The last report has more especial reference to the curve for 1846, and plate 25. (vol. 1847) illustrates the departure from symmetry as we proceed from Brussels to the north-west. The most prominent results of this branch of our subject, up to the last meeting of the Association, has been the determination that each station possesses its own barometric type; that at other stations, more or less, according to their distance or proximity, certain differences from this type obtain: these differences are strikingly exhibited in plate 25, Report, 1847. Such a result was certainly to be expected, as the points of intersection of each wave of each system must necessarily be *different* at different stations, so that the barometric curves at the various stations must necessarily differ from each other. The constancy of the symmetrical characters of the curves appertaining to the middle of November renders it important to deduce the mean symmetrical curve for the fifteen days constituting the period of the "great wave," for as many stations as observations can be obtained from. Without doubt, the mean curve at Brussels would be highly valuable; it has, however, been out of our power to determine it during the last year; but the Greenwich observations have afforded the opportunity of determining the mean curve

for that station, from the observations 1841 to 1845 inclusive, already published.* In deducing this mean curve, the epochs given in the following table have been regarded as marking the transit of the apex of the symmetrical curve in each year.

TABLE VIII.

Epochs of transit of the crest of the "Great Symmetrical Wave of November," from 1841 to 1845 inclusive, at the Royal Observatory, Greenwich.

Year.	Epoch of transit.	Altitude of crest.
	d h	
1841.	Nov. 25, 0	29·693
1842.	Nov. 17, 22	30·470
1843.	Nov. 13, 10	30·170
1844.	Oct. 26, 22	30·157
1845.	Nov. 14, 0	29·948

These epochs have consequently been considered as the axes of the curves; they have been brought in the projections on the same vertical line, and on this line the altitudes given in the third column have been projected; the altitudes at intervals of two hours preceding and succeeding these axes during a period of thirty days have also been projected, so that fifteen days on each side complete not only the symmetrical curves, but also those preceding and succeeding them by seven days. During a period embracing 192 hours preceding and succeeding the apices, means have been taken, when practicable, of the two-hourly readings, from which the mean curve has been projected; these means are recorded in the following Table, and the mean curve projected below the symmetrical curves for each year. On Plate 3 will be found the five curves of the symmetrical wave for the years abovementioned, also the mean symmetrical curve deduced from them.

TABLE IX.

Mean ordinates of the "Great Symmetrical Wave of November," as deduced from Observations at the Royal Observatory, Greenwich, during the years 1841 to 1845 inclusive, corrected for temperature, and reduced to the level of the sea.

Hours before transit. −	Altitudes.	Hours after transit. +	Altitudes.	Hours before transit. −	Altitudes.	Hours after transit. +	Altitudes.
Apex.	30·271	Apex.	30·271	20	30·112	20	30·173
2		2		22	·092	22	·172
4		4		24	30·079	24	·151
6		6		26		26	·135
8		8	30·256	28		28	·114
10	30·215	10	30·252	30	29·992	30	·097
12	·205	12		32		32	·085
14	·189	14		34	29·959	34	·070
16	·160	16	30·209	36	29·944	36	30·038
18	30·132	18	30·184	38		38	

TABLE IX. (*continued*).

Hours before transit. −	Altitudes.	Hours after transit. +	Altitudes.	Hours before transit. −	Altitudes.	Hours after transit. +	Altitudes.
40		40		118		118	29·392
42		42		120	29·637	120	·379
44		44		122		122	29·369
46	29·848	46		124		124	
48	·848	48	29·900	126		126	
50	·820	50		128		128	
52	·790	52		130		130	
54	·765	54		132	29·581	132	29·393
56	·754	56		134	·567	134	·375
58	·723	58		136	·553	136	·361
60	·694	60		138	·526	138	29·337
62	·658	62		140	·518	140	
64	·608	64		142	·518	142	
66	·563	66		144	·529	144	
68	·558	68		146	·529	146	
70	·575	70	29·809	148	·530	118	29·279
72	·582	72		150	·535	150	·276
74	·569	74		152	29·539	152	·304
76	·557	76		154		154	·324
78	·548	78	29·823	156		156	·356
80	·563	80		158		158	29·386
82	29·587	82		160	29·506	160	
84		84		162		162	
86		86	29·740	164		164	
88		88	.688	166		166	
90		90	·622	168	29·572	168	29·462
92	29·660	92	·564	170		170	
94		94	·551	172		172	
96	29·697	96	·520	174		174	
98		98	·497	176		176	29·392
100		100	·473	178	29·604	178	
102		102	·463	180	·634	180	
104		104	·478	182	·662	182	
106		106	·490	184	·697	184	29·362
108		108	·485	186	·733	186	·367
110		110	·459	188	29·770	188	·361
112		112	·435	190		190	·561
114		114	·419	192		192	29·374
116	29·623	116	29·409				

Essential features of the barometric type for November, known as the Great Symmetrical Wave of November, as exhibited in a mean curve deduced from five years' observations at the ROYAL OBSERVATORY, GREENWICH.

It has been assumed that the great symmetrical wave of November consists of *five* subordinate waves giving rise to the five maxima which charac-

terize it, the central maximum forming the apex of the symmetrical curve, the remainder being subordinate thereto (Report, 1846, p. 125). Upon a close inspection of the curves of the "great wave" as laid down from the Greenwich observations, six subordinate maxima can be traced, three on each side the central apex, which in all the years is by far the most prominent. The mean curve leads to the conclusion that *Greenwich is not the point of greatest symmetry*, its closing portion being depressed more than 0·2 inch below the commencement. The most striking feature is the decided rise of the mercurial column during a period of 68 hours preceding the transit of the crest. The value of this rise is 0·7 inch, or about 0·010 inch per hour. The fall is not so precipitous; the barometer appears to be *kept up* in this locality by the *first subordinate maximum* succeeding the crest; so that at the epoch of 68 hours after transit, the value of the reading is more than 0·2 inch higher than at 68 hours before transit. At 80 hours after transit a precipitous fall commences which continues during the next 24 hours, the mercury sinking 0·36 inch, or about 0·015 per hour; the fall afterwards continues, with two slight interruptions, answering to the subordinate maxima until the close of the wave 148 hours after transit, the entire depression being nearly 1 inch.

It is worthy of remark, that in the determination of the symmetrical curve from the Greenwich observations, extending in each year over double the period embraced by the curve itself, and including five instead of three years, the period of the wave should so closely agree with the period assigned to it in 1845 when the ordinates of the mean normal curve were deduced from the recurring curves of 1842, 1843, and 1844 (Report, 1845, p. 122), the observations in 1842 having been made at Leicester Square, and those in the last two years at Cambridge Heath. The two periods are identical, viz. 296 hours. It is necessary to mention here that so close an accordance in the values of the ordinates is not to be expected. The Greenwich observations have been corrected for temperature, and the mean ordinates are reduced to the level of the sea. The quantities employed in the deduction of the ordinates recorded on p. 122, Report, 1845, were obtained from observations as read off from the scale without any correction whatever.

The barometric rise, to which allusion has been made, was very distinct on the occasion of the return of the great symmetrical curve in 1846. I have recorded in my last report (Report, 1847, pp. 359 to 363) the phænomena of this rise as exhibited in Great Britain and Ireland, especially during the first 50 hours, and it is not difficult to recognise them as repetitions of the phænomena from which the mean rise has been deduced.

As regards the departure from symmetry manifested by the mean curve at Greenwich, the first portion of the curve, viz., from 148 hours to 68 hours before transit, being thrown *higher* than the latter portion, that from 92 hours to 148 hours after transit, and the bulging character of the fall occasioning the readings at similar epochs to be higher after transit than before, during a period of 90 hours preceding and succeeding the transit of the crest, it appears pretty evident that this station is removed a definite distance from the point of greatest symmetry. If we take the commencement and termination of the wave at equal altitudes as indicating the greatest symmetry, the departure from symmetry at any station will be measured by the difference between the altitudes of the beginning and end; thus the mean departure from symmetry at Greenwich, from the five years' observa-

tions, using these elements, may be expressed as ·251 inch. Other features of the mean curve may be employed for this purpose; but whatever value may be adopted as a measure of the departure from symmetry, the points of the curves from which such value has been deduced should be particularly specified.

PART III.

The possibility of measuring at any one station the departure from symmetry which that particular curve known as the "symmetrical curve" manifests, brings us to the third part of this report,—"The notice of any results that may have been obtained during the past year of a character not contemplated, or but slightly indicated in our former reports, and which have particularly originated in the observations of the last return of the November curve." The "symmetrical curve" on its last return was very distinct; it however presented some minor features which occasioned it to differ slightly from the *type*, as expressed in the Report of 1846, p. 125. The central apex was depressed at London below two of the subordinate maxima on either side. Had these subordinate maxima exhibited the same altitudes, and the interior minima preceding and succeeding the central apex also exhibited similar altitudes, the symmetry on the last return would have been complete at London, although the central apex was lower than those preceding and succeeding it; as it was, the first maximum, that of the 10th, was depressed ·051 inch below that of the 18th, the second. We have accordingly indicated, both from the mean curve as deduced from the Greenwich observations and the features of the "symmetrical curve" as it passed London during the last autumn, a mode of expressing numerically the deviation from symmetry at any station; and it is clear that this deviation may be expressed for single years, as deduced from the individual curves, or the mean deviation may be taken from several years' observations, as we have done for Greenwich. The last method would be the most desirable in determining the value of the deviation at other stations. We are not, however, in possession of series of observations executed at such short intervals, extending over so long a period, and noting such minute changes of pressure as the Greenwich observations, in other parts of Great Britain, and also in Ireland; nor can we find observations even at longer intervals at stations sufficiently near each other to enable us to determine either the law of the departure from symmetry as we recede from the point of greatest symmetry, or the directions in which such deviations increase more rapidly than in others, by this method; but we may attempt some approximation to the determination of such a law, or the indication of such directions, by taking certain points of the symmetrical curves for individual years, as indicated by the observations of last autumn regarding the differences between such points as measures of the deviations from symmetry, and constructing charts of equal deviation. The observations forming the subject of my last report, embracing as they do the whole of Great Britain and Ireland, are admirably suited for such an attempt. I have accordingly selected the maxima of the 5th and 12th (see plate 25, Report, 1847) as the points from which the deviation from symmetry may be deduced, and laid down on a map of the British Islands the differences between these maxima, and from them have constructed the lines of equal deviation from ·050 inch to ·550 inch, being nearly the range of these differences.

TABLE X.

Values of the deviation from symmetry of the great symmetrical curves of November, as deduced from the depression of the maximum of the 5th of November below that of the 12th in the year 1846 in Great Britain and Ireland.

Station.	Deviation from symmetry.	Station.	Deviation from symmetry.
Stornoway	·580	Hobbs' Point....	·313
Limerick	·550	Nottingham	·285
Galway	·480	Brecon	·270
Largs	·460	Gloucester	·260
St. Vigean's.....	·440	Helstone	·258
Orkneys........	·420	Cirencester......	·244
Makerstoun	·407	Weston	·210
Applegarth......	·400	London	·171
Bowness........	·360	Ramsgate	·100
Newcastle	·343	Jersey	·013

In the chart accompanying this report (Pl. 4), the line representing the deviation from symmetry by ·300 inch, or in other words, that line of country on which the maximum of the 5th did not attain the elevation of that of the 12th by this quantity, is probably the best determined; it appears to have passed a little to the north-west of Cornwall, to the south-east of Pembrokeshire, north-west of Brecon, west of Nottingham, and south-east of Newcastle. The ·250 inch line is also well determined by the observations at Helstone, Weston, Gloucester, Cirencester, and Nottingham. The observations at Helstone, Brecon, Gloucester, and Nottingham mark out very distinctly the direction of the line ·260 inch; this line passes very near and to the west of Helstone, ·258; it then proceeds along the coasts of Cornwall and Devonshire, crosses the Bristol Channel, enters Wales, and continues its progress across Glamorganshire towards Brecon, which it leaves to the north-west, ·270 inch being the value at this station. It is at this point that it appears to undergo a decided inflexion, its course being changed rather abruptly as it proceeds to Gloucester, which city it passes through. Nottingham is removed ·025 from it to the west; and the bend in the central parts of England is very considerable to bring it again to its original direction, as it leaves the land at the south-east angle of Yorkshire and enters on the German Ocean. These lines of equal deviation from symmetry present a very remarkable characteristic, namely, a decided inflexion over the land forming the central parts of England. This inflexion is borne out by the London and Ramsgate observations, presenting higher values of these differences than they would have done had the lines extended across England without inflexion. The general direction of the lines in the central and south-east parts of England is S.W. to N.E. The observations from Scotland and Ireland indicate that the general direction in those localities approached nearer to that of the meridian; the lines are, however, inflected as they pass over the land. The chart exhibits *two* systems of inflexion, viz. that of Ireland and England, the general direction of the lines undergoing a change as the line of greatest symmetry is approached, the inflexion being governed apparently by the masses of land; and the other in Scotland, the observations at the Orkneys, St. Vigean's, and Largs affording

conclusive evidence relative to it. It would consequently appear, in accordance with previous researches (Report, 1846, p. 147), that contiguous masses of land and water exert a decided and measurable influence on the variations of atmospheric pressure. In the case before us, the symmetry of the barometric curve is departed from in a greater degree at inland stations, a greater difference between the points selected being exhibited at such stations than at the sea-coast on either side.

On turning to the last Report, pp. 357 and 358, we find the maximum of the 5th referred to a wave-crest that passed rather rapidly over the area from the *south-west*. The altitude of this crest was greatest in the south-east, simply because it was contemporaneous with a north-westerly slope; a line from Jersey to Limerick on the chart will somewhat approximate to a transverse section of this slope. On page 364 of the same report, we find the maximum of the 12th referred to a wave-crest that came from the north-west; and at p. 367, the departure from symmetry is referred to the greater development of this north-westerly wave. Stornoway, in the Western Isles, exhibited the greatest development of this wave, the greatest barometric range during the passage of the "symmetrical curve," and the greatest difference between the points selected as indicating the departure from symmetry; and these phænomena clearly resulted from the greater altitude which the north-westerly wave attained in the north of Scotland; this would appear to indicate that the deviation from symmetry resulted from the greater altitude of the north-westerly wave in certain localities, and that the barometer had a tendency to rise higher over the land as the wave transited. It is, however, difficult to determine this from the observations, partly on account of the slow-moving wave [I] (Report, 1847, p. 358), whose crest extended from Arbroath to Stornoway, and also from the south-westerly system of waves; for it is evident that the same result, viz. an approach to an equality of altitude of the maxima of the 5th and 12th, would be produced as well by the *higher* readings of the 5th as the *lower* readings of the 12th. Upon the whole it appears highly probable that the result is a compound one, the approach to symmetry, as we proceed from the north-west to the south-east, being occasioned by the higher readings of the south-westerly crest of the 5th in the south-east, and the lower readings of the north-westerly crest of the 12th in the same locality; the inflexions of the lines being produced by the tendency of the barometer to rise higher as the anterior slopes and crests, especially of the north-west wave, passed over the land.

Regarding the chart before us as indicating the localities and directions of certain barometric phænomena characterizing the "great symmetrical curve of November," we at once see that it exhibits to us but a small portion of the area over which these particular phænomena can be traced. The lines of deviation from symmetry, as determined from observation, extend from ·100 inch at Ramsgate to ·550 inch at Limerick, ·580 inch being the highest determination at Stornoway. It would appear from the Galway observations that the deviation did not much exceed ·580 inch, ·480 inch being the value at this station. *Query*. Shall we find the curves undergoing such a modification of form to the north-west of Ireland and Scotland as to bring these maxima more on a level, having other features, as the broad maximum of the 8th, which is very apparent in the Galway curve, so developed as to produce a different order of curves, the limit of deviation from symmetry of the Greenwich type being somewhat in the direction of the ·550 inch line? The area of the British Isles embraces the north-western side of the deviation from symmetry, as determined by the inferiority of the maximum

of the 5th to that of the 12th. How far the lines of deviation extend to the south-west and north-east we are at present ignorant: it would however be interesting to learn whether they continue to any great extent to exhibit a more or less longitudinal direction, being simply inflected by the masses of land over which they pass, or whether they form a system of curves, the interior ones being closed. Of the direction and form of the lines of equal deviation to the south-east of the symmetrical line we are likewise ignorant. Taking the Jersey curve, *although not the most symmetrical*, yet, with regard to the points selected, exhibiting the least deviation, we find a development of a different and somewhat opposite character to that which we observe in the Scottish and Irish curves. In these curves the maximum of the 12th is by far the most prominent, that of the 5th appearing as very subordinate. At Jersey that of the 5th is the most prominent, the maximum of the 12th dwindling into a subordinate elevation on the posterior slope of the curve. *Query*. Does the maximum of the 5th rise into considerable importance south-east of the line of greatest symmetry, while that of the 12th merges into the general curve so as to give rise to a series of lines of equal deviation of an opposite character to those which we have traced; and do these lines of opposite deviation preserve a general parallelism within certain limits to them? If so, the lines of equal and opposite deviation on each side the line of greatest symmetry, whether extending indefinitely or forming closed curves, will mark out an area to which that particular barometric curve known as the "symmetrical curve of November" is peculiar, and the line of greatest deviation on each side will to a certain extent limit such area, curves of a different character, and exhibiting novel features, appearing beyond the lines of greatest deviation.

It may probably be inquired if the general direction of the lines of equal deviation are similar year after year? The amount of our present knowledge on this head indicates that such is not the case: taking similar points in the curve on each return as indicating the departure from symmetry, the direction of the lines varies, and this variation appears to be in accordance with a certain law. We have on former occasions noticed that in 1842 the direction of the line of greatest symmetry was from Dublin to Munich, the deviations occurring on the north-east and south-west of this line (Report, 1846, p. 163). In 1845 it appeared to be in the direction of the southern shores of England (Report, 1846, pp. 139, 164), and it consequently formed, with the line of greatest symmetry in 1842, a considerable angle. In 1846 this angle was considerably increased; and from some observations received last autumn, it appeared to be still further increased, so as to equal if not exceed a right angle, the station affording the most symmetrical curve being Norwich. The *instability* of the line of greatest symmetry, to which allusion has been made in my Report of 1846, p. 126, is thus clearly established and the character of the motion indicated. The line of greatest symmetry appears to revolve around a fixed point or node, which is situated in the neighbourhood of Brussels*. It is probable the node itself is situated a little to the north-west of Brussels, the common intersection of the lines already traced occurring to the north-west of that city.

W. R. BIRT.

Postscript. I omitted to mention in my last Report, in connexion with the observations made at the stations recorded in Table I. (Report, 1847, p. 351), that the observations at Sir Thomas Brisbane's observatory, Makerstoun, near Kelso, were made under the sole direction of J. A. Brown, Esq.

* Sir John Herschel has directed attention to the nodal character of Brussels in his Report on Meteorological Reductions (Report, 1843, p. 100), especially in relation to the revolution of the wind in one uniform direction.

On Colouring Matters. *By* Edward Schunck.

In the report which I had the honour of presenting last year to the British Association on Colouring Matters, I gave the results of my investigation of the colouring matters of madder. This investigation I have continued and brought to a conclusion. The subject has however proved so extensive, the number of questions arising in regard to this valuable and extensively-used tinctorial substance being very great, that I have been unable to examine any other colouring matters very minutely.

I stated in my last report, that when finely-ground madder roots are treated with hot water, a brown liquid is obtained having a sweetish bitter taste, in which acids produce a dark brown precipitate. This precipitate I stated to consist of six substances, viz. two colouring matters, two fats, pectic acid and a bitter substance. To these I now add a seventh: it is a dark brown substance which remains behind when the other substances have been removed by means of boiling water and alcohol; it is soluble in caustic alkalies with a dark brown colour, and seems to be the substance to which the colour of the dark brown precipitate is due: I consider it to be oxidized extractive matter. Concerning the method of separating the other six substances contained in the dark brown precipitate, I have nothing to add to what I said in my last report, as I have not been able to discover a shorter or better plan of separating them than that which is there described. In regard to their nature, properties and composition, which I have examined more minutely, I shall in this report give a number of additional details; before doing so however I shall make a few observations on the subject in general. I may state, in the first place, that I have arrived at the conclusion that there is only one colouring matter contained in madder, viz. alizarin; the other substance, which I took for a colouring matter in the first instance, and which I called rubiacin, I now consider to be no colouring matter at all, for reasons which I shall presently state. I have also reason to believe that the two substances which in my first report I called fats, are not fats, but resins; they are coloured resins similar to many others known to chemists. Of these two resins I shall call the more easily fusible one, which dissolves in a boiling solution of perchloride or pernitrate of iron, the *alpha-resin*; the other less easily fusible one, which forms an insoluble compound when treated with perchloride or pernitrate of iron, the *beta-resin*. The method of preparing them is the same as that which I described in my former report. After the dark brown precipitate produced in a decoction of madder by acids has been successively treated with boiling water and boiling alcohol, there remains behind a dark brown substance; on treating this substance with caustic potash, it dissolves in great part with a dark brown colour; on filtering there remains on the filter a mixture of peroxide of iron and sulphate of lime; on adding a strong acid to the filtered liquid a substance in dark brown flocks is precipitated, which is thrown on a filter, washed and dried. This substance, when heated on platinum foil, burns without much flame, and leaves a considerable ash. It is easily decomposed by boiling dilute nitric acid, which converts it with an evolution of nitrous acid into a yellow flocculent substance. As it is insoluble in all menstrua except the alkalies, it may be asked, how it can be extracted from madder by means of boiling water, in which it is of itself insoluble, and whether it is not possible that it may be formed during the process of boiling by the action of the air on some substance contained in the extract. I think the latter supposition very probable,

and I shall presently describe a substance of almost identical properties formed by the action of the air on xanthin, the extractive matter of madder. There can however be no doubt that the brown colour of the precipitate, which is produced by acids in a decoction of madder, is due to this substance, for the other bodies contained in it are not brown, but yellow or orange-coloured in a precipitate state. This dark brown precipitate therefore consists of the following substances:—alizarin, rubiacin, alpha-resin, beta-resin, rubian, pectic acid, and oxidized extractive matter.

I have examined the liquid filtered from the dark brown precipitate produced by acids more minutely since making my last report. If oxalic acid be used as the precipitant, the excess of acid may afterwards be removed by chalk, without leaving any lime-salt in solution. The liquid, which had a light yellow colour, was evaporated on the sand-bath. During evaporation it gradually became brown, and left at last a thick dark brown syrup, which never became dry, however long it might be exposed to the heat of the sand-bath. On re-dissolving this syrup in water, a considerable quantity of a dark brown powder remained behind. On again evaporating the filtered solution on the sand-bath, an additional quantity of this powder was deposited, just as in the case of extractive matter. There can be no doubt that this powder is formed by the action of the air, assisted by heat, on some soluble substance contained in the liquid. On burning a small quantity of the brown syrup in a crucible it swelled up enormously, and gave off a quantity of empyreumatic products, which burned with a flame, leaving at last a considerable quantity of white ash; this ash was partly soluble, partly insoluble in water. The soluble part had a strong alkaline reaction; it consisted of a trace of lime and magnesia, and a great deal of potash, combined with carbonic, sulphuric and muriatic acids. The insoluble part consisted of carbonate of lime, carbonate of magnesia, a trace of alumina, phosphate of lime and phosphate of magnesia. The solution of the brown syrup in water had an acid reaction. It gave no precipitate or peculiar colour with a persalt of iron, and therefore contained no tannic acid. The addition of alcohol produced no precipitate or coagulate, and therefore there was no gum present. On adding muriatic or sulphuric acid to it, and then boiling, it became dark-coloured and deposited a green powder. Sugar of lead produced in the solution a dirty brown flocculent precipitate, and basic acetate of lead a still more copious precipitate. A considerable quantity of the brown syrup was dissolved in water, and basic acetate of lead was added until no more precipitate was produced. The precipitate was separated by filtration, and washed with water. The percolating liquid had a yellow colour. The excess of lead was removed from it by sulphuretted hydrogen, and the filtered liquid was evaporated over sulphuric acid, since, if evaporated by the assistance of heat, the substance contained in it was changed by the air, became brown, and deposited a brown powder. After remaining over sulphuric acid for several weeks, there was left a yellow or brownish-yellow syrup like honey, which did not become dry. This substance, though not pure (as it contained salts of lime, magnesia and potash), I conceive to be identical with Kuhlmann's xanthin and Runge's madder-yellow.

If madder contains sugar, it is evident that, provided the method of operating described above be followed, it must be contained in the same liquid as this xanthin. I have however not been able to prove its presence by direct experiment; but I have succeeded in ascertaining indirectly that madder does in reality contain sugar of some kind by means of the following experiment. Half a hundred-weight of madder was treated with boiling

water for several hours. The liquor, after being reduced by boiling to a convenient compass, was mixed with some yeast, and allowed to ferment. By distillation an alcoholic liquid was obtained, which, after a second distillation, gave 21½ ozs. of alcohol of sp. gr. 0·935, which is equivalent to 9 ozs. of absolute alcohol. It is therefore evident that madder contains sugar of some kind or other.

The precipitate produced by basic acetate of lead in the solution of the brown syrup was decomposed with sulphuretted hydrogen. The filtered liquid was evaporated, and left after evaporation a dark brown syrup, having a strongly acid taste and reaction. The brown colour was no doubt due to xanthin in its oxidized state. After being repeatedly dissolved, and the solution being each time evaporated, a dark brown powder was deposited, just as in the case of the original solution: nevertheless the acid taste always remained. It might be supposed that this taste was due to some vegetable acid; and indeed if any such acid, or the compound of any one with the alkalies or earths, had been extracted from the madder by boiling water, it would most probably have been precipitated by the basic acetate of lead, and it would be in the liquid obtained by the decomposition of the lead precipitate that we should have to look for any such acid. Now the syrup obtained after decomposing the lead precipitate and evaporating the liquid, though intensely acid, contained no oxalic, tartaric, malic or citric acid; neither did it show the least sign of crystallization; but the watery solution gave a crystalline precipitate with ammonia and sulphate of magnesia; and after destroying the brown organic matter contained in it by adding nitric acid and boiling, and then evaporating to drive away the excess of nitric acid, it gave a yellow precipitate with nitrate of silver and ammonia. I therefore infer that the acid to which the sour taste of the brown syrup was owing, was phosphoric acid*. The sulphuret of lead, produced by the decomposition of the lead precipitate, was treated with boiling caustic potash. A dark brown solution resulted, which after filtration gave with muriatic acid a dark brown precipitate. This precipitate, after filtration, washing and drying, cohered into masses, which were brittle and black, but became brown when powdered. It was totally insoluble in boiling water and alcohol. It was decomposed by dilute boiling nitric acid, and changed into a yellow flocculent substance. It was soluble in concentrated sulphuric acid, forming a brown liquid, and was re-precipitated by water. I consider this substance, that formed in a solution of xanthin during evaporation by heat, and the dark brown substance contained in the precipitate produced by acids in a decoction of madder as the same, and that they are all produced from xanthin by the action of the oxygen of the air.

It still remains for me to say a few words on the substances left behind in the root, after madder has been exhausted with boiling water. It has for some time been well known that if madder, which has already been used for the purpose of dyeing, be treated with a strong acid such as sulphuric or muriatic, and the acid be then carefully removed by washing with cold water, it is capable of being again used for dyeing in the same way as fresh madder. It is in this manner that the article known in commerce as *garanceux* is

* On one occasion, after having added nitric acid to the acid syrup and boiled, I obtained on evaporation crystals of an organic acid, very similar to alizaric acid, but not identical with it. It was sparingly soluble in cold water, but very soluble in hot. It was volatile. The watery solution gave with acetate of lead a crystalline precipitate soluble in boiling water, with perchloride of iron a cream-coloured precipitate, with acetate of copper a green crystalline precipitate, and with nitrate of silver and ammonia a white flocculent precipitate. Alizarate of lead is quite insoluble in boiling water, and not in the least crystalline.

manufactured. This is a convincing proof that it is impossible to extract the whole of the colouring matter by means of boiling water, and that part of it must remain behind in some state in which it is insoluble in water. A quantity of madder was treated with boiling water until the liquor gave absolutely no more precipitate on the addition of muriatic acid. A very long boiling was necessary for this purpose. The colour of the madder was changed by this process from yellowish-brown, as it appears in the fresh state, to a dull red. It was then treated with boiling caustic potash ley. A liquor of a brownish colour was obtained, in which muriatic acid produced a gelatinous precipitate of a brown colour. This was separated by filtration, and, after being washed with cold water in order to remove all the muriatic acid, was treated with a large quantity of boiling water, in which it proved to be almost entirely soluble. The solution was light brown. It gave gelatinous precipitates with acids, with lime and baryta water, alcohol and most salts. On evaporation it left a substance in light brown, transparent, brittle scales, which turned out to be pectic acid, much purer indeed than that obtained in the first instance from the aqueous decoction. No colouring matter, or any other substance besides pectic acid, seemed to be extracted by the caustic alkali.

Another quantity of madder which had been completely exhausted by boiling water, was treated with boiling muriatic acid, and the liquid, after the boiling had been kept up for some time, was strained through a cloth and supersaturated with ammonia, which produced a pinkish-white precipitate. This precipitate was thrown on a filter and carefully washed. The liquid contained an abundance of lime and magnesia. A part of the pinkish-white precipitate was dried and heated to redness in a crucible. During ignition a gas came off which was without odour, and burnt with a blue flame, being probably carbonic oxide. After complete ignition it dissolved in muriatic acid with an effervescence of carbonic acid, but without leaving much carbonaceous residue. On adding ammonia to the solution a white precipitate was again produced. The filtered liquid contained a large quantity of lime and a trace of magnesia. The precipitate consisted of alumina, peroxide of iron, phosphate of lime, and a trace of phosphate of magnesia. As it became probable from the preceding reactions that the pinkish-white precipitate contained oxalate of lime, the rest of it was treated with boiling dilute sulphuric acid. The liquid after filtration was evaporated. It gave crystals which were dissolved in alcohol to separate the sulphate of lime. The alcohol on evaporation gave colourless crystals of pure oxalic acid. Hence I infer that the following substances were extracted from the madder by means of muriatic acid :—lime, magnesia, oxalate of lime, phosphate of lime, alumina and peroxide of iron. The madder which had been subjected to the action of muriatic acid was now well-washed with water, and then treated with boiling caustic potash ley. A dark red solution was obtained, which, after being strained through a cloth, produced, on being supersaturated with an acid, a dark reddish-brown precipitate. This precipitate was thrown on a filter, and well-washed with cold water, to remove the excess of acid. I found this precipitate to dye mordanted cloth quite full, and of the same colours as madder itself. There could therefore be no doubt about its containing alizarin. Moreover, on treating the precipitate with boiling alcohol, a brownish-yellow liquid was obtained, which left on evaporation a brownish-red residue. A small portion of this residue being heated between two watch-glasses, an abundance of orange-coloured crystals of sublimed alizarin appeared on the upper glass. By treating the precipitate with boiling water,

and filtering boiling hot, the liquid deposited on cooling orange-coloured flocks, which were impure alizarin, for they dyed mordanted cloth, and after being dried and heated in a tube, they gave a crystalline sublimate. The liquid gave on evaporation pectic acid. That part of the precipitate which was left undissolved by boiling water, was treated with a boiling solution of nitrate of iron. The filtered liquid gave, on the addition of muriatic acid, a slight yellow precipitate, which was probably rubiacic acid from the rubiacin of the precipitate. The greater part was insoluble in nitrate of iron. By treating the insoluble residue with boiling muriatic acid, filtering, washing with water, and treating with boiling alcohol, an abundance of beta-resin was procured.

I infer from these experiments that the substances extracted from madder by caustic potash, after exhaustion with boiling water and treating with acid, previously existed in the root in combination with lime and magnesia; that these substances are not different from those extracted by boiling water, viz. alizarin, rubiacin, resins and pectic acid; that the compounds of these bodies with lime and magnesia are insoluble in water, and, with the exception of pectate of lime, insoluble in caustic alkalies; and that therefore, in order to extract them by means of water or an alkali, it is first necessary to remove the lime and magnesia with which they are combined by means of an acid.

I shall now proceed to give some further details concerning the properties and composition of the substances extracted from madder.

Alizarin.—Concerning the properties of alizarin I have nothing to add to what I stated in my last report, except that when crystallized from alcohol it contains several atoms of water of crystallization, which it loses when heated to 212° F. The crystals after being heated to this point have not lost their shape, but have become opake and of a much redder colour, resembling that of native chromate of lead. On placing them in a tube immersed in a sulphuric-acid bath, and heating the bath, no further change takes place until about 420° F., when a sublimate of orange-coloured crystals begins to appear on the cold part of the tube.

On subjecting alizarin to elementary analysis I obtained the following results:—

I. 0·3205 grm. of crystallized alizarin dried in the air gave, on being burnt with chromate of lead, 0·6695 carbonic acid and 0·1210 water.

II. 0·3985 grm. of the same gave, 0·8320 carbonic acid and 0·1850 water.

III. 0·3140 grm. gave 0·6565 carbonic acid and 0·1670 water.

These numbers correspond in 100 parts to—

	I.	II.	III.
Carbon	56·97	56·94	57·02
Hydrogen	4·19	5·13	5·87
Oxygen	38·84	37·93	37·11
	100·00	100·00	100·00

The great discrepancy in the amounts of hydrogen in the preceding analyses arises from the circumstance that alizarin loses its water of crystallization with such extreme facility. No. I. was mixed with warm chromate of lead in a warm mortar; No. II. was mixed with warm chromate of lead in a cold mortar; and No. III. with cold chromate of lead in a cold mortar. In the case of No. I. therefore we see that the heat of the chromate of lead and the mortar combined was sufficient to drive away more water than what corresponds to 1½ per cent. of hydrogen, though this heat was not greater than what might be borne by the hand. In order to determine the amount of

water of crystallization, crystallized alizarin was heated in a water-bath until it lost no more in weight.

I. 0·4015 grm. treated in this way lost 0·0735 water.

II. 0·3575 grm. lost 0·0655 water.

Alizarin which had been deprived of its water of crystallization by heat, gave, on being burnt with chromate of lead, the following results:—

I. 0·2990 grm. gave 0·7575 carbonic acid and 0·1045 water.

II. 0·3005 grm. of a different preparation gave 0·7620 carbonic acid and 0·1095 water.

III. 0·2765 grm. of the same preparation as the preceding gave 0·7010 carbonic acid and 0·1025 water.

In 100 parts it contains therefore—

	I.	II.	III.
Carbon	69·09	69·15	69·14
Hydrogen	3·88	4·04	4·11
Oxygen	27·03	26·81	26·75
	100·00	100·00	100·00

On analysing alizarin prepared by sublimation from pure crystals, I obtained the following numbers:—

I. 0·3970 grm. gave 1·0115 carbonic acid and 0·1340 water.

II. 0·4110 grm. gave 1·0510 carbonic acid and 0·1375 water.

In 100 parts—

	I.	II.
Carbon	69·48	69·73
Hydrogen	3·75	3·71
Oxygen	26·77	26·56
	100·00	100·00

It will be seen from this that sublimed alizarin does not differ materially in composition from alizarin which has been freed from its water of crystallization.

Of the compounds of alizarin with bases I prepared the lime, baryta and lead compounds. The two former were prepared by dissolving alizarin in ammonia, and precipitating with chloride of calcium and chloride of barium, the latter by dissolving alizarin in alcohol and precipitating with an alcoholic solution of sugar of lead. The latter forms a purple precipitate, which, after standing for some hours, becomes of a dull red.

The lead compound gave on analysis the following numbers:—

I. 0·4800 grm. gave 0·2095 oxide of lead and 0·0245 metallic lead, equivalent to 0·2359 oxide of lead.

0·5125 grm. burnt with chromate of lead gave 0·7050 carbonic acid and 0·0780 water.

II. 0·5865 grm. of a different preparation gave 0·3970 sulphate of lead, equivalent to 0·2920 oxide of lead.

0·6915 grm. gave 0·9370 carbonic acid and 0·1005 water. Hence was deduced the following composition:—

		Calculated Numbers.	Found. I.	Found. II.
14 eqs. Carbon......	84	37·57	37·51	36·95
4 „ Hydrogen ..	4	1·78	1·67	1·61
3 „ Oxygen	24	10·75	11·70	11·65
1 „ Oxide of lead	111·7	49·90	49·12	49·79
	223·7	100·00	100·00	100·00

The lime compound gave the following results:—

I. 0·4685 grm. gave 0·2065 sulphate of lime, equivalent to 0·0857 lime.

II. 0·4750 grm. gave 0·2125 sulphate of lime, equivalent to 0·0882 lime.

Assuming that the formula for this compound is $C_{14} H_4 O_3 + CaO + HO$, its composition would be as follows:—

		Calculated Numbers.	Found. I.	Found. II.
1 eq. Alizarin	112	74·91		
1 „ Water........	9	6·03		
1 „ Lime	28·5	19·06	18·30	18·58
	149·5	100·00		

The baryta compound gave the following:—

0·2450 grm. gave 0·1420 sulphate of baryta, equivalent to 0·0932 baryta.

Assuming that the formula of this compound is similar to that of the last, viz. $C_{14} H_4 O_3 + BaO + HO$, its composition would be as follows:—

		Calculated.	Found.
1 eq. Alizarin	112	56·65	
1 „ Water..............	9	4·57	
1 „ Baryta	76·68	38·78	38·03
	197·68	100·00	

Neither of these compounds loses the equivalent of water which it contains on being heated in a water-bath for several hours.

The composition of crystallized alizarin must therefore be as follows:—

		Calculated.
14 eqs. Carbon	84	56·75
8 „ Hydrogen	8	5·40
7 „ Oxygen	56	37·85
	148	100·00

or,

		Calculated Numbers.	Found*. I.	Found*. II.
1 eq. dry Alizarin	121	81·76		
3 eqs. Water	27	18·24	18·33	18·32
	148	100·00		

It follows that alizarin dried at 212° must consist of—

		Calculated.
14 eqs. Carbon	84	69·42
5 „ Hydrogen	5	4·13
4 „ Oxygen	32	26·45
	121	100·00

If this be the true composition of alizarin, it follows that there exists a very singular relation between it and the composition of benzoic acid. The formula of benzoic acid is $C_{14} H_6 O_4$, and alizarin only differs from it therefore by containing one equivalent less of hydrogen. If we compare alizarin with isatin, we shall find that the latter only differs from the former by containing in addition the elements of one equivalent of cyanogen. The formula of isatin is $C_{16} H_5 NO_4 = C_{14} H_5 O_4 + C_2 N$. Anthranilic acid differs in composition from alizarin in containing in addition the elements of amidogen, for the formula of anthranilic acid is $C_{14} H_7 NO_4 = C_{14} H_5 O_4 + NH_2$.

* See p. 62.

Alizaric Acid.—In my former report I stated that alizarin, when treated with concentrated solutions of persalts of iron, is converted into a new acid, which I called alizaric acid. I stated at the same time that I thought it probable that alizaric acid might also be formed by acting on alizarin with nitric acid. This supposition has since been confirmed. On treating pure crystallized alizarin with boiling nitric acid, it is decomposed with an evolution of nitrous acid, and the liquid on evaporation gives crystals of alizaric acid. It is however not necessary to prepare pure alizarin in order to obtain alizaric acid. I have found the following to be the easiest method:—Nitric acid of about sp. gr. 1·20 having been put into a retort, garancin is introduced into the acid, and the liquid is heated until the red fumes have ceased to be evolved, and the colour of the garancin has changed from dark brown to yellow. The reddish-yellow acid liquid which is obtained, is filtered or strained to separate it from the woody fibre, &c. of the garancin, and evaporated to crystallization. A yellow crystalline mass is obtained, which is a mixture of oxalic acid and impure alizaric acid. After being washed with cold water to remove the excess of nitric acid, the mass is dissolved in boiling water, and chalk is added until all effervescence and acid reaction have ceased. The liquid is filtered, and the oxalate of lime remaining on the filter is washed with boiling water, until no more lime can be detected in the percolating liquid. The liquid is a solution of alizarate of lime. Muriatic acid is added to it, and it is evaporated to crystallization. A yellow mass is again obtained, which may be washed with cold water to remove the chloride of calcium, then redissolved in boiling water. It forms a yellow solution, which may be almost decolorized by animal charcoal. On again evaporating, the alizaric acid is obtained in large crystals. Should these crystals still retain a yellow tinge, which is generally the case, they must be redissolved in boiling water. By passing chlorine gas through the boiling solution, until every trace of colour has disappeared, perfectly colourless crystals of the acid are obtained on cooling. Prepared in this way, it appears in large flat rhombic plates: it has the properties which I described in my last report.

The salts of alizaric acid are mostly soluble. Alizarate of potash is formed by neutralizing a watery solution of alizaric acid with carbonate of potash: it is obtained on evaporation as a deliquescent mass. Alizarate of lime is prepared by neutralizing alizaric acid with carbonate of lime, and evaporating to crystallization. It crystallizes in prisms, possessing great lustre. Alizarate of baryta, prepared in the same way by means of carbonate of baryta, crystallizes in silky needles. Alizarate of silver, prepared by double decomposition, is soluble in boiling water, from which it crystallizes on the solution cooling. Alizarate of lead is an insoluble white powder, obtained by precipitation of the acid with sugar of lead. With ammonia alizaric acid does not seem to form a neutral salt. On supersaturating a solution of the acid with ammonia and evaporating, the solution acquires during evaporation an acid reaction, and at length a salt crystallizes out in flat plates, which is no doubt a superalizarate of ammonia. All the salts of alizaric acid, when strongly heated, are decomposed with an evolution of a fragrant smell similar to that of benzin, and give, as a product of the decomposition, a thick brown oil, to which without doubt the smell is owing; while the carbonates of the bases, or the bases themselves, remain behind mixed with much charcoal.

The elementary analysis of alizaric acid gave the following results:—

I. 0·5250 grm. obtained by means of perchloride of iron and burnt with oxide of copper, gave 1·1015 carbonic acid and 0·1810 water.

II. 0·4670 grm. obtained by means of nitric acid and burnt with chromate of lead, gave 0·9865 carbonic acid and 0·1685 water.

III. 0·4475 grm. of the same preparation as the preceding gave 0·9360 carbonic acid and 0·1625 water.

IV. 0·4395 grm., purified by means of chlorine and burnt with chromate of lead, gave 0·9335 carbonic acid and 0·1510 water.

These numbers give in 100 parts—

	I.	II.	III.	IV.
Carbon	57·20	57·61	57·10	57·92
Hydrogen....	3·83	4·00	4·03	3·81
Oxygen	38·97	38·39	38·87	38·27
	100·00	100·00	100·00	100·00

Alizarate of lead was analysed with the following results :—

I. 0·8110 grm. gave 0·2665 oxide of lead and 0·2160 metallic lead, equivalent to 0·4991 oxide of lead.

0·6660 grm. gave 0·5810 carbonic acid and 0·0915 water.

II. 0·6230 grm. gave 0·2040 oxide of lead and 0·1655 metallic lead, equivalent to 0·3822 oxide of lead.

0·6515 grm. gave 0·5560 carbonic acid and 0·0860 water. Hence was deduced the following composition :—

			Calculated Numbers.	Found.	
				I.	II.
14 eqs.	Carbon	84	23·37	23·79	23·27
4 „	Hydrogen ..	4	1·11	1·52	1·46
6 „	Oxygen	48	13·37	13·15	13·93
2	Oxide of lead	223·4	62·15	61·54	61·34
		359·4	100·00	100·00	100·00

The baryta salt lost nothing in weight on being heated for several hours in a water-bath.

I. 0·6725 grm. of baryta salt dried at 212° gave 0·5245 sulphate of baryta, equivalent to 0·3442 baryta.

II. 0·7330 grm. gave 0·5700 sulphate of baryta, equivalent to 0·3740 baryta.

Its composition is therefore probably as follows :—

		Calculated.	Found.	
			I.	II.
1 eq. anhydrous Acid .	136	46·26		
1 „ Water	9	2·36		
2 eqs. Baryta	153·3	51·38	51·18	51·03
	298·3	100·00		

It is probable that the silver salt also contains two equivalents of base to one of acid.

It follows from the analysis of the lead salt, that the hydrated acid has the following composition :—

		Calculated.
14 eqs. Carbon	84	57·93
5 „ Hydrogen	5	3·44
7 „ Oxygen	56	38·63
	145	100·00

By the action of nitric acid on alizarin the latter takes up three equivalents

of oxygen without losing any hydrogen, for $C_{14} H_6 O_4 + 3O = C_{14} H_6 O_7$. It appears also that alizaric acid contains one equivalent of hydrogen less, and three equivalents of oxygen more, than benzoic acid.

Pyro-alizaric Acid.—When alizaric acid is heated it is totally volatilized, and forms a sublimate in the shape of long white needles, to which I have given the name of pyro-alizaric acid. By the action of heat alizaric acid loses water, or the elements of water. Pyro-alizaric acid is soluble in boiling water. The solution, however, produces exactly the same reactions as alizaric acid itself, and on evaporation large rhombic crystals are obtained, which have quite the appearance of the latter acid. It is probable therefore that, by solution in water, pyro-alizaric acid takes up again the elements of water, and is reconverted into alizaric acid. The following results were obtained on analysing this acid:—

I. 0·4405 grm. dried at 212° and burnt with chromate of lead, gave 1·0345 carbonic acid and 0·1185 water.

II. 0·4255 grm. gave 0·9985 carbonic acid and 0·1215 water.

From these numbers it may be inferred that the composition is as follows:—

		Calculated Numbers.	Found.	
			I.	II.
28 eqs. Carbon	168	63·87	64·04	63·99
7 „ Hydrogen	7	2·66	2·98	3·17
11 „ Oxygen	88	33·47	32·98	32·84
	263	100·00	100·00	100·00

Hence it follows that by the action of heat two equivalents of alizaric acid lose three equivalents of water, and give one equivalent of pyro-alizaric acid, since $2(C_{14} H_5 O_7) - 3HO = C_{28} H_7 O_{11}$.

Rubiacin.—In my last report I described the method of preparation, and the properties of rubiacin and rubiacic acid, and I have nothing further to add to what I there stated. I may mention however that I have arrived at the conclusion that rubiacin cannot be considered as a true colouring matter, as it is impossible to dye with it. I shall also show that, contrary to the opinion which I was led to entertain in the first instance, rubiacin does not contribute to produce any effect in the process of madder-dyeing.

On subjecting rubiacate of potash and rubiacic acid to analysis, I obtained the following results:—

I. 04490 grm. rubiacate of potash gave 0·1090 sulphate of potash, equivalent to 0·0589 potash.

0·4350 grm. gave 0·7950 carbonic acid and 0·0900 water.

II. 0·3245 grm. gave 0·0790 sulphate of potash, equivalent to 0·0427 potash.

0·2890 grm. gave 0·5315 carbonic acid and 0·0665 water.

From these numbers it may be inferred that the salt is composed as follows:—

		Calculated Numbers.	Found.	
			I.	II.
31 eqs. Carbon....	186	51·63	51·50	51·82
7 „ Hydrogen..	7	1·94	2·29	2·55
15 „ Oxygen ..	120	33·31	33·09	32·47
1 „ Potash	47·27	13·12	13·12	13·16
	360·27	100·00	100·00	100·00

I. 0·3785 grm. rubiacic acid, dried at 212° and burnt with oxide of copper, gave 0·7940 carbonic acid and 0·0845 water.

II. 0·3605 grm. of another preparation gave 0·7610 carbonic acid and 0·0795 water.

III. 0·4670 grm. of the same preparation as the preceding gave 0·9775 carbonic acid and 0·1050 water.

Hence was deduced the following composition :—

			Calculated Numbers.	Found.		
				I.	II.	III.
31 eqs.	Carbon ..	186	57·76	57·21	57·57	57·08
8 „	Hydrogen	8	2·48	2·48	2·45	2·49
16 „	Oxygen ..	128	39·76	40·31	39·98	40·43
		322	100·00	100·00	100·00	100·00

0·3150 grm. rubiacin, dried at 212° and burnt with oxide of copper, gave 0·7740 carbonic acid and 0·0935 water.

This gives the following composition :—

			Calculated.	Found.
31 eqs.	Carbon........	186	67·63	67·01
9 „	Hydrogen	9	3·27	3·28
10 „	Oxygen	80	29·10	29·71
		275	100·00	100·00

The formula of rubiacin being $C_{31} H_9 O_{10}$, and that of rubiacic acid $C_{31} H_8 O_{16}$, it follows that when rubiacin is converted into rubiacic acid, it loses one equivalent of hydrogen and takes up six equivalents of oxygen, and that when rubiacic acid is reconverted into rubiacin, it loses six equivalents of oxygen and takes up again one of hydrogen. This oxidation and reduction is accomplished with the same certainty and precision as any similar process with inorganic bodies.

Alpha-resin.—This resin is a constituent of the dark brown precipitate produced by acids in a decoction of madder. It dissolves together with rubiacin, when this precipitate is treated with a boiling solution of perchloride or pernitrate of iron, and is precipitated together with rubiacin and rubiacic acid when muriatic acid is added to the solution. It is separated from the rubiacin and rubiacic acid by means of alcohol, in which it is easily soluble, while the two former are but little soluble. It has a dark brown or reddish-brown colour. When cold it is brittle, and may be easily pulverized. It begins to become soft at 150° F., and melts to dark brown drops between 200° and 212°. When heated on platinum-foil it melts, swells up, and burns with flame, leaving much charcoal, which however burns away without leaving any residue. When heated in a glass tube it swells up, gives an oily sublimate, and evolves a strong smell, leaving at last a bulky carbonaceous residue. It is slightly soluble in boiling water, to which it communicates a yellow tinge. On the solution cooling yellow flocks are deposited, which are increased in quantity by adding an acid. It dissolves in alcohol with an orange colour; water makes the solution milky, and on the addition of an acid the resin is completely precipitated in orange-coloured flocks. The alcoholic solution does not redden litmus paper. It dissolves in concentrated sulphuric acid with a dark orange colour, and is re-precipitated by water in yellow flocks. It is decomposed by boiling concentrated nitric acid; on evaporating the acid a resinous mass is left. It dissolves in caustic and carbonated alkalies with a purplish red colour. The solution in ammonia does not lose its ammonia on boiling, but on evaporation the resin is left in combination with a little

ammonia. The ammoniacal solution gives purple precipitates with the chlorides of barium and calcium, and a dirty red precipitate with alum. It dissolves in perchloride and pernitrate of iron with a dark reddish-brown colour, and is re-precipitated by acids in flocks. The alcoholic solution gives red precipitates with alcoholic solutions of sugar of lead and acetate of copper. If chlorine be passed through a solution of the resin in caustic potash, it is decolorized; acids however now produce no precipitate, so that the resin seems to have been entirely decomposed by the chlorine. If mordanted cloth be introduced into boiling water, in which a quantity of the resin is suspended, the alumina mordant acquires an orange colour, and the iron mordant a brown colour. Nevertheless these colours are so slight, that it is not likely that this resin contributes in any way to produce the desired effect in the process of madder-dyeing. I shall presently show that, on the contrary, it is rather injurious than otherwise in this process, since those parts of the cloth which should remain white acquire from it a disagreeable yellow tinge, which cannot afterwards be removed by merely washing with water, so that even if it did contribute to produce any greater intensity of colour on the mordanted parts, the advantage would be more than counterbalanced by the injurious effect on the unmordanted parts.

Beta-resin.—This resin also forms a constituent of the dark brown precipitate produced by acids in a decoction of madder. If this precipitate be treated with a boiling solution of perchloride or pernitrate of iron, the beta-resin forms a compound with peroxide of iron, which remains undissolved. By decomposing this compound with muriatic acid, and dissolving the resin in boiling alcohol, it is deposited on the alcohol cooling as a light brown powder. It hardly melts at the temperature of boiling water, but merely becomes soft and coheres into lumps. When heated on platinum foil, it melts and burns, leaving a slight red ash. When heated in a glass tube, it gives yellow fumes and evolves a disagreeable smell, leaving a carbonaceous residue. It is slightly soluble in boiling water, to which it communicates a yellow tinge; on the solution cooling nothing separates, but on adding acid some yellow flocks are deposited, while the liquid becomes colourless. The alcoholic solution is dark yellow; it reddens litmus-paper. Water renders it milky, and acids precipitate the resin completely in yellow flocks. The resin dissolves in concentrated sulphuric acid with a dark brown colour, and is re-precipitated by water in light brown flocks. Concentrated nitric acid dissolves it on boiling and decomposes it; on evaporation there is left a yellow, bitter astringent substance. It dissolves in caustic and carbonated alkalies with a dirty red colour, inclining to purple in the case of caustic alkali. It is re-precipitated by acids in brown flocks. If chlorine be passed through a solution of the resin in caustic potash, it is decolorized; but the substance itself seems to be thereby decomposed, as acids afterwards produce only a slight precipitate. The ammoniacal solution gives with the chlorides of barium and calcium dirty yellow precipitates. The alcoholic solution gives with an alcoholic solution of sugar of lead a red precipitate, and with an alcoholic solution of acetate of copper a brown precipitate. The ammoniacal solution loses its ammonia on evaporation, and the resin is left as a transparent brown skin. This resin has the same effect on mordanted cloth as the preceding; the alumina mordant acquires an orange, and the iron mordant a brown colour, while the unmordanted parts become yellow and unsightly. These effects are not however so decided as in the case of the alpha-resin, which is probably owing to its being less soluble in water than the latter.

Rubian.—I have given this name to the substance to which the bitter taste

of madder seems to be due. I have described its method of preparation and properties in my last report. I may state, in addition to what I there said, that rubian seems to be a nitrogenous body, since, on treating it with boiling caustic alkali, ammonia is evolved. This fact and the bitter taste seem to indicate that the medical properties of madder, if indeed it possesses any, reside in this substance.

If a solution of rubian in water be evaporated in contact with the air and with the assistance of heat, it deposits a dark brown substance, which sinks to the bottom in resinous drops, so that on treating the residue after evaporation with water, it is not completely re-dissolved; and if the filtered liquid be again evaporated as before, a fresh quantity of the dark brown substance is formed, just as in the case of extractive matter. This dark brown substance melts into drops in boiling water, but when cold it is brittle. It dissolves in alkalies with a dark red colour, and is re-precipitated by acids in yellow flocks; indeed it bears in all respects a great resemblance to the body which I have called alpha-resin. Nevertheless it seems to consist of more than one substance; for if it be heated in a glass tube over a lamp, an abundant sublimate, consisting of shining yellow crystals, is obtained in the upper part of the tube: these crystals very much resemble rubiacin. If it be treated with a boiling solution of perchloride or pernitrate of iron, the liquid becomes reddish brown, and gives after filtration a yellow precipitate with muriatic acid, which is a proof of its containing either alpha-resin or rubiacin, or both. Hence it becomes very probable that rubiacin, the alpha-resin, and perhaps also the beta-resin, are formed from rubian by the action of the oxygen of the air. It becomes still more probable when we consider the following facts:—If an infusion of madder with cold water be allowed to stand in contact with the air, it will be found that after some hours the liquid is filled with a number of long hair-like crystals, which are, as I have shown on a previous occasion*, rubiacin, generally mixed with a substance having all the properties of beta-resin. I have had one specimen of madder which gave such quantities of rubiacin on allowing the infusion to stand, that it collected on the surface of the liquor as a bright yellow scum, and by crystallizing it from alcohol it was obtained almost in a state of purity. Now as rubiacin is insoluble in cold water, it must in this case either have been formed from some substance contained in the infusion by the action of the air, or else it was at first held in solution by some other substance, such as an alkali or alkaline earth from which it gradually became separated, as by the formation of some acid in the liquid. I incline to the former supposition, and think it probable that it is the rubian which by its oxidation gives rise to the rubiacin.

Xanthin.—This substance, the method of preparing which from a decoction of madder after the separation of the colouring matters, &c. by acid, I have described above, is of course not a pure substance, since after ignition it leaves a considerable quantity of fixed residue: it is also probable that it contains a small quantity of sugar, as I stated before. Nevertheless it produces reactions of a peculiar kind, which cannot be attributed to sugar, gum, or any similar substance, and can only be due to a peculiar body which exists only in madder. It has the following properties:—When prepared as above described, it is a thick, viscid, yellow or brownish-yellow syrup, resembling honey in colour and consistency, which cannot be rendered dry even by exposing it to a heat at which it begins to be decomposed. When exposed to the air, it becomes more liquid on account of its attracting moisture. When

* See the Report of the British Association for the Advancement of Science for 1846.

heated to ignition, it swells up enormously, giving off at the same time a very perceptible smell of aceton and burns, leaving at last a considerable quantity of ash, which consists of the carbonates of lime, magnesia and potash. It is without doubt the acetates of those bases which, being mixed with the substance, produce the smell of aceton during ignition. The acetic acid was of course derived from the basic acetate of lead used in the preparation of xanthin, and the acid with which they were originally combined must have gone to the oxide of lead. Now, as I stated above, the oxide of lead was found to be combined with phosphoric acid; hence it is probable that the greater part, if not all, of the fixed bases left after the ignition of the xanthin existed in the plant as phosphates. Xanthin has a disagreeable taste, between bitter and sweet. The watery solution is yellow. It is soluble in alcohol, and is left after evaporation in the same state as before. It is insoluble in æther. On adding muriatic or sulphuric acid to the watery solution and boiling for some time, a peculiar smell is evolved, the solution becomes gradually dark green, and a dark green powder is deposited. This is the most characteristic property of xanthin. Nitric acid does not produce the same dark green powder, or any deposit on boiling; nevertheless the powder which has once been formed by means of muriatic or sulphuric acid, is not dissolved by boiling nitric acid, but only turned yellow. Acetic acid produces no effect. Oxalic acid gives a white precipitate of oxalate of lime. Bichromate of potash and sulphuric acid produce no effect on a solution of xanthin, even on boiling. On adding caustic potash to the solution it turns brown, and on boiling a slight smell of ammonia is evolved. Lime and baryta water, acetate and basic acetate of lead, the acetates of alumina, iron and copper, nitrate of silver, corrosive sublimate, and a solution of glue, produce no precipitate or effect whatever in a solution of xanthin. In fact it does not seem to be precipitated by any reagent whatever without undergoing decomposition.

If a clear light yellow watery solution of xanthin be evaporated with the assistance of heat and in contact with the air, as on the sand-bath, to a syrup, and this syrup be again mixed with water and the solution again evaporated, the process being several times repeated, the solution gradually becomes dark brown, and at length a dark brown powder is deposited. The brown solution now gives with acetate, or basic acetate of lead, a thick brown precipitate. The filtered liquid is yellow, and if the excess of lead be removed by sulphuretted hydrogen, the solution again gives, on evaporation over sulphuric acid, a colourless or light yellow syrup, which however, if redissolved and evaporated with the assistance of heat as before, again becomes dark brown, and deposits a dark brown powder. There can therefore be no doubt that this brown powder is a product of the oxidation of xanthin, that xanthin is a species of extractive matter, and that the brown powder stands in the relation to it of an *apothema*. This brown powder has the following properties:—When dry it is a dark brown mass, easily reduced to powder. It is quite insoluble in boiling water and boiling alcohol. It burns without flame, leaving much ash. It is soluble in concentrated sulphuric acid with a dark brown colour, and is re-precipitated by water. Boiling dilute nitric acid decomposes it with an evolution of nitrous acid, and changes it into a yellowish-red flocculent substance. Concentrated nitric acid on boiling decomposes and dissolves it entirely. It dissolves in caustic and carbonated alkalies with a dark brown colour, and is re-precipitated by acids in light brown flocks. The ammoniacal solution gives brown precipitates with the chlorides of barium and calcium. The dark green powder which is produced

by the action of sulphuric and muriatic acid on xanthin, has the following properties:—When dry it has a dark olive colour. It burns with a flame and a smell like burning wood, leaving a large quantity of charcoal, which however burns away without any fixed residue. It is decomposed by boiling dilute nitric acid, and changed into a yellow flocculent substance. It is insoluble in concentrated sulphuric acid, and also in boiling alcohol. When treated with caustic potash, a part dissolves with a dark brown colour, and is re-precipitated by acids as a dark brown powder, while the other part remains undissolved as a black powder.

Mordanted cloth acquires no colour in a boiling solution of xanthin, if the latter is in its yellow unoxidized state; but if the solution has become brown by contact with the air, then both the alumina and the iron mordant acquire in the boiling solution a brown colour, while the unmordanted parts, which should remain white, become of a brown tint. Hence it follows that xanthin is injurious in madder-dyeing, and must contribute, together with the two resins, in impairing the purity of the colours, and sullying the whiteness of those parts which should attract no colour. To get rid of the xanthin is one object of changing madder into garancin.

It remains for me to say a few words in regard to the part which the different substances described above play in the process of madder-dyeing. I regret to say that in my last report there are contained some views on this head, which I have found, on more exact investigation, to be erroneous. The two principal points to be determined are, which is the substance that produces the chief effect in dyeing with madder, and why is a certain proportion of lime, either in the plant or in the dye-bath, necessary for the production of fine and durable colours. In my last report I stated it as my opinion, that both alizarin and rubiacin take part in the process, that rubiacin alone produces no effect, but that when it is in combination with an alkali or an alkaline earth, it forms double compounds with the alizarin compounds of alumina and peroxide of iron, and thus increases the intensity of colour in the latter. I have since found that this opinion cannot be sustained, since rubiacin, whether free or combined, produces no beneficial effect in the process of dyeing, and is therefore no true colouring matter, as the following experiments will show.

Since the brown precipitate produced by acids in a watery extract of madder contains all the free colouring matter of the root, and acts in dyeing in the same way as madder itself, it was evident that by trying the constituents of this precipitate in conjunction with one another, both in a free state and in combination with lime, a correct view of the part performed by each would be arrived at. Having therefore taken a piece of calico on which three mordants had been printed, one for red, one for purple, and one for black, in alternate stripes, each stripe being one quarter of an inch broad, and having intervals between them of the same width, it was divided into pieces of six inches by three, and one of these pieces was taken for each of the following experiments. As the tinctorial power of alizarin is very great, so great that one quarter of a grain was enough to over-dye one of these pieces, I took one or two grains of crystallized alizarin, dissolved it in a measured quantity of water, to which a little caustic alkali had been added, and was then able to divide the solution into portions corresponding to quarters, eighths, and sixteenths of a grain, so that by precipitating one of these portions with muriatic acid, filtering and carefully washing, I obtained small quantities in a state very well adapted for dyeing. By treating one of these

quantities while on the filter with lime-water, and washing out the excess of lime, I obtained small quantities of the lime compound of alizarin for the same purpose. The same process was used for obtaining small quantities of rubiacin, alpha-resin, beta-resin, pectic acid and rubian, and their lime compounds. Each experiment was performed with the same quantity of water, at as nearly as possible the same temperature, and occupied the same length of time, viz. half an hour. The substances used, and their quantities, were as follows:—

1. $\frac{1}{8}$ grain of alizarin.
2. $\frac{1}{16}$ gr. alizarin.
3. $\frac{1}{16}$ gr. alizarin and $\frac{1}{16}$ gr. alizarin in combination with lime.
4. $\frac{3}{32}$ gr. alizarin and $\frac{1}{32}$ gr. alizarin in combination with lime.
5. $\frac{1}{8}$ gr. alizarin and $\frac{1}{8}$ gr. rubiacin.
6. $\frac{1}{8}$ gr. alizarin and $\frac{1}{8}$ gr. rubiacin in combination with lime.
7. $\frac{3}{32}$ gr. alizarin and $\frac{1}{32}$ gr. rubiacin in combination with lime.
8. $\frac{1}{8}$ gr. alizarin and $\frac{1}{2}$ gr. pectic acid.
9. $\frac{1}{8}$ gr. alizarin and $\frac{1}{2}$ gr. pectic acid in combination with lime.
10. $\frac{1}{8}$ gr. alizarin and $\frac{1}{8}$ gr. alpha-resin.
11. $\frac{1}{8}$ gr. alizarin and $\frac{1}{8}$ gr. alpha-resin in combination with lime.
12. $\frac{1}{8}$ gr. alizarin and $\frac{1}{8}$ gr. beta-resin.
13. $\frac{1}{8}$ gr. alizarin and $\frac{1}{8}$ gr. beta-resin in combination with lime.
14. $\frac{1}{8}$ gr. alizarin and $\frac{1}{8}$ gr. rubian.
15. $\frac{1}{8}$ gr. alizarin and $\frac{1}{8}$ gr. rubian in combination with lime.

Now the following results were obtained:—No. 1 was everything that could be desired in regard to all the colours. No. 2 was of course only half as dark. No. 3 was lighter than No. 1, and the white parts had a pink hue. No. 4 was a little darker than No. 3, but not as dark as No. 1. No. 5 was much inferior to No. 1; the red had an orange hue, the purple a reddish cast, and the black was brown, while the white was yellowish. No. 6 was equal to No. 1, but not darker, and in no respect superior. No. 7 was about equal to No. 4. No. 8 had almost no colour at all; the red, the purple and the black were mere tinges of colour, such as might probably have been produced by the tenth part of the quantity of alizarin employed, if no pectic acid had been present. No. 9 was again equal to No. 1. No. 10 was lighter than No. 1, the purple especially being pale and reddish, while the white parts were yellowish. No. 11 was equal to No. 1, but not superior. No. 12 was exactly the same as No. 10, the purple having a disagreeable reddish cast, while the white parts were yellowish. No. 13 was again equal to No. 1. No. 14 and 15 did not differ from one another, and were equal to No. 1. Hence we may draw the following conclusions:—Alizarin produces the greatest effect in dyeing when used alone. The addition of lime, even in very small quantities, does not increase its tinctorial power, but on the contrary neutralizes the effect of that portion with which it combines. Rubiacin, the alpha-resin and the beta-resin, in a free state, when used in conjunction with alizarin, are injurious in about the same degree: they weaken the red, the black, and especially the purple, while they render the white part yellowish. In combination with lime these substances do not increase the tinctorial power of alizarin, they merely allow it to act without hindrance. Pectic acid almost destroys the effect of alizarin. Pectate of lime is perfectly indifferent. Rubian in a free state, and in combination with lime, has neither a beneficial nor an injurious effect. Of all the substances therefore contained in madder, none is of use in dyeing but alizarin, while all the others are injurious when in a free state. That which is the most hurtful is pectic acid.

When alizarin and pectic acid are present together in the dye-bath, the pectic acid having most affinity for bases, combines with the alumina and peroxide of iron, and the alizarin crystallizes out when the bath cools, as I noticed in performing the experiment No. 8. The same is without doubt the case when using rubiacin or the resins. The alumina and peroxide of iron combine with these substances to the exclusion of the alizarin; and these compounds are either colourless, or have a poor and unsightly colour. The use of lime is therefore easily explained; it serves, not to increase the tinctorial power of the colouring matter, but to combine with and render harmless the substances which are injurious in a free state. Now if we treat madder with muriatic or sulphuric acid, we remove all the lime and magnesia from it; the pectic acid, the rubiacin and the resins become free; and if we wash with water, the muriatic or sulphuric acid is certainly removed; but those substances being but little soluble in cold water, remain and destroy the effect of the alizarin in dyeing. But if previous to dyeing we add lime, the pectic acid, the rubiacin and the resins being more electro-negative than alizarin, combine with the strongest base which is the lime; and the alizarin, which is less electro-negative, combines with the weakest bases, viz. the alumina and peroxide of iron. If we add an excess of lime, then of course the alizarin also combines with the lime, and the alumina and peroxide of iron having no free body to combine with, remain colourless. The process is thus brought into harmony with our previous knowledge of the relative affinity of acids and bases. It is probable that lime is not absolutely necessary for the success of the operation, and that it might be replaced by potash, soda, magnesia or baryta; but as lime is the cheapest substance that can be used for the purpose, it would be of no practical importance to find a substitute for it.

I have in the preceding remarks left xanthin out of consideration. During the process of madder-dyeing this substance no doubt becomes oxidized, and deposits the brown substance mentioned above on all parts of the cloth. This substance, together with the pectic acid, the rubiacin and the resins, are removed afterwards by passing the cloth through a boiling solution of soap. The alkali of the soap dissolves these substances, which have more affinity for alkalies than alizarin, while the fat acid remains on the cloth in combination with the alizarin, the alumina and the peroxide of iron.

In order to prove analytically that alizarin is the substance which produces madder colours, I took several yards of cloth which had been dyed purple with madder, but not soaped, and treated it with muriatic acid, which removed the oxide of iron, and left an orange-coloured substance on the cloth. After washing the cloth in cold water until all the acid had been removed, it was treated with caustic alkali. The brownish-red solution thus obtained was supersaturated with an acid, and the reddish-brown precipitate formed was thrown on a filter and well washed with cold water: it was then treated with boiling alcohol. The alcoholic liquid, which was dark yellow, was spontaneously evaporated, and gave crystals of alizarin mixed with a powder resembling beta-resin, and a few yellow micaceous plates, which were probably rubiacin. There remained a brown residue insoluble in alcohol, part of which dissolved in boiling water, and proved to be pectic acid. On treating some cloth which had been dyed with madder, and then soaped, with muriatic acid as before, and then with caustic alkali, I obtained a purple solution, in which acids produced a yellow precipitate. This precipitate was treated with boiling alcohol like the other; it gave a yellow liquid, which on evaporation

afforded crystals of alizarin, together with white masses of fat acid. Hardly any residue remained undissolved by the alcohol.

The preceding observations have a great bearing on the manufacture and treatment of garancin. Garancin is the technical name for a preparation of madder, which is obtained by treating madder with hot sulphuric acid until it has acquired a dark brown colour, then adding water, straining and washing until all the acid is removed. The advantages which garancin has over madder are, that it dyes finer colours, that the part destined to remain white does not acquire any brown or yellow tinge, and that its tinctorial power is greater than that of the madder from which it has been prepared. These effects have been attributed to various causes. It has been asserted that the sulphuric acid destroys the gum, the mucilage, the sugar, &c., and leaves the colouring matter unaffected; hence the greater beauty of garancin colours. To account for the greater proportional effect of garancin, it has been said that a part of the colouring matter is enclosed in cells of the wood, so that it cannot be dissolved by water, and that the sulphuric acid destroys the wood and liberates the colouring matter. To these views it may be objected, that concentrated sulphuric acid, though it does not affect alizarin, does not destroy any of the injurious substances in the root except the xanthin, while the rubiacin, the resins, and the pectic acid, escape its action: and as far as the wood is concerned, I can affirm that the operation succeeds equally well if acid be taken of such dilution as not to destroy woody fibre. I think that the superiority of garancin can only be attributed to two causes. In the first place, since, as I have shown above, there is a quantity of colouring matter in the root combined with lime and magnesia, by which it is rendered insoluble and incapable of dyeing, one effect of the acid is to remove this lime and magnesia, and to set the alizarin at liberty, which is then capable of application. In the second place, the xanthin, which has an injurious effect in madder-dyeing, is removed by washing with cold water, since it is not precipitated by acids, while the whole of the alizarin remains. If hot acid is employed, then the xanthin, or a part of it, is converted into that dark green substance which I have mentioned above as the product of the action of muriatic and sulphuric acid on xanthin; hence the dark colour of garancin, which is not owing to the charring of the woody fibre, as sometimes asserted. It must be remembered however that the rubiacin, the resins and the pectic acid, as well as the alizarin, remain uncombined after treatment with acid. Hence it becomes necessary to add some base with which these substances may combine, so as not to interfere with the action of the alizarin. I believe it is the practice of garancin manufacturers to employ soda for this purpose. I think it would be better to use a small quantity of lime-water.

I may state in conclusion that the experiments described in this and the last report were made with Avignon madder. The constituents and properties of Dutch madder, which is of rather a different nature, remain to be examined.

I have been lately engaged in examining the colouring matter of fustic, which I have prepared in a state of purity, but the investigation is not sufficiently advanced to justify me in making known the results on the present occasion.

On the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works. By JAMES PALMER BUDD.

[A Communication ordered to be printed entire among the Reports.]

I AM glad of the opportunity of laying before the distinguished scientific and practical men who are gathered together at this meeting of the British Association, what I believe to be one of the most important practical improvements that has yet been introduced into the iron trade, and the application of which will, if my views are correct, probably lead to a radical change in the smelting of iron ores, and the manufacture of iron in this country.

As a practical man, I shall first treat of practical results, and I think myself fortunate that I have to bring this subject forward in a locality where I am inevitably brought in contact with many who are intimately acquainted with the details of the iron trade. I have had the pleasure to exhibit to many members of the British Association, the improvements I shall describe in operation on a large scale at Ystalyfera, and I shall feel pleasure in affording any others, who take an interest in the subject, full opportunity for investigation. If I venture to suggest, beyond my positive results, the practicability, or I think I might say the certainty of an enormous œconomy, by the further development of the system I have partially introduced at Ystalyfera, I do so only because the facts and results arrived at irresistibly point onward to greater improvement and œconomy.

The iron trade of Great Britain is so enormous in extent, that any œconomy in its processes which admits of general application, becomes of national importance. Even if the saving on the current expense be small as a tonnage, the multiple of the annual quantity of iron produced is so great as to make the total gigantic. Thus, taking the annual produce of iron in Great Britain in round numbers to be 1,500,000 tons, or about 500,000 tons made in England, 500,000 tons in Wales and Monmouthshire, 500,000 tons in Scotland, a saving of even 1*s.* per ton on the cost of production amounts to the large sum of £75,000 a-year.

There is no detail of the iron trade that has appeared to me to be more a standing reproach to its management, than the non-utilization in this country of the enormous escape of combustible and incombustible gases, heated to a very high temperature, that is constantly taking place from the tops of blast furnaces. Some of these enormous crucibles yield 150 tons, in Scotland even 200 tons of iron a week, and these devour internally from 300 to 400 tons of coal weekly, and respire 4000 and 5000 cubic feet of air as blast a minute. These great craters vomit forth murky volumes of smoke and flame, which pass wastefully and uselessly away to contaminate the atmosphere. So great and obvious a source of heat has not failed however to attract the attention of ingenious men, but more especially so, since it was found advantageous to heat the blast of air before injecting it into the furnace. The use of hot-blast at the tuyères, could not fail to suggest the application of some part of the waste heat about the furnace to the purpose of giving the desired temperature, which is the moderate one of 600 degrees of Fahrenheit only.

Unfortunately these attempts took two wrong directions; one series of attempts consisted in either ranging iron pipes around the tunnel head, in which the blast was to be heated by the flames as they escaped, or in coiling pipes round the interior of the furnace, so as to be heated by contact with the ignited materials themselves; or blast pipes were built into the masonry, so as to receive heat by transmission without being however in contact with the

burning material; but in all cases the contrivance formed part of the furnace itself. All these several obsolete plans are shown in the drawings of an elaborate work on Hot-Blast, published officially at Freiberg in 1840, which contains drawings of all the different apparatus that have been known in England, Wales, Scotland, Belgium, Germany, and Sweden. The fatal objection to these plans for heating the blast was, that in case of derangement of the apparatus, the operations of the furnace had to be suspended during repair; and even according to several of the schemes, it would have been necessary to blow out the furnace itself, and take it down in order to repair a leaky joint. These attempts were speedily relinquished, and I am not aware that any plan of the kind is in operation in the iron trade abroad, certainly not in this country. Another series of attempts took an opposite direction. The top of the furnace was either partially or wholly closed, except during charging; the gases were thus collected and carried to a reservoir or gasometer; they were passed through water to be cooled and purified; air-pumps were employed to force them towards the point, where they were afterwards to be burnt in a gas furnace. Several patents have been taken out for this application, the first as early as 1838, but, although tried in various works, I do not know that any plan of the sort is in use in this country. It was found that the combustible gases collected from the furnace were so diluted with nitrogen (itself incombustible and incapable of supporting combustion), that it required two conditions to burn them in so mixed a state:—1st. That a blast of air should be employed. 2nd. That such blast should be heated. When once ignited, the heat produced by these gases, consisting of carbonic oxide and hydrogen partly in combination with carbon, is intense, so much so, that the tops and sides of the gas-furnace were speedily melted down. Still, if this plan of consuming the gases to produce heat, instead of being directed to stoves and boilers, had been employed as abroad, to carry on the processes of converting pig-iron into malleable iron, which require a very high temperature and a steady fire, with a limited admission of air, I think practice would have perfected the details and conquered the obstacles; but in this country of cheap fuel, the gases being ignited merely to heat the blast or to raise steam, requiring only a temperature of melting lead and boiling water, and for purposes where a high temperature cannot be employed without danger, it was found a fatal objection that a blast machine had to be provided, and a hot-blast apparatus kept at work to impart the necessary temperature for the gas furnace; thus of course reducing, and in fact destroying, all the saving to be effected, besides complicating the operations of the furnace by additional machinery and apparatus.

This want of simplicity has led to the abandonment of the gas-furnace in this country as a means of consuming the vapours escaping from the tops of blast-furnaces. At this point I found the subject, when four years ago my attention was attracted to it. Truly necessity quickens invention, and but for an obvious difficulty under which I laboured, I fear I also should have allowed the huge volumes of flame and vapour to pass off as heretofore unheeded. But I laboured under two serious disadvantages at Ystalyfera in employing the hot-blast. First, as the furnaces working on anthracite coal cannot be made to drive like coke-furnaces, although they burden heavily, the make is only 50 or 60 tons of iron per furnace weekly, and falling on this small weekly quantity, I had the cost of the hot-blast apparatus, consisting of three stoves or heating furnaces, consuming about 35 tons of coal together a week, and requiring the attendance of two men, one by day and one by night; next, as the small or slack of anthracite coal burns very imperfectly in a reverberatory furnace from its not caking at all, so that the draught of a chimney

is not sufficient to ensure a passage of air through the grate, I was obliged to use for the stoves coal of a rubbly size, and consequently of increased cost. In this way I found the charge on the ton of iron, of heating the blast, very onerous, as compared with other districts where larger quantities of iron per furnace are made, and where the small of bituminous coal is used for the heating ovens. Fortunately, in my attempts to use the escape from the tunnel head to heat my blast of air, I neither made my apparatus part of the furnace, nor did I attempt to burn the gases. I built my stove alongside the furnace, of which however it forms no part, and by means of a stack about 25 feet higher than the top of the furnace, I was enabled to draw into it as much of the heated air and flame as I required. The result of this plan has been a most perfect success, from its thorough simplicity. I interfere in no way with the operations of the furnace; everything is as before; my apparatus is merely three or four horizontal flues of about 12 inches diameter, constructed about 3 feet below the top of the furnace and leading into an adjoining chamber or stove, provided with a stack which makes the draught. Into this stove I am enabled to draw as much of the gaseous escape as I require, and by means of a damper on the stack (what is equally important), as little as I choose. The quantity required to produce hot-blast for a furnace is very little, not being more, as far as I can judge, than one-sixth of the quantity passing off the tunnel head. I attempt no combustion of the gases, for as they rise from the furnace and enter the stove with a temperature of about 1800 degrees, and leave it at a temperature of about 800 degrees, whilst all the heat I require for the blast is about 600 degrees, the mere passage of them, as heated vapours through the stove, gives me all the temperature I want; whilst having no combustion going on, the pipes remain uninjured, the bricks unmelted, and the apparatus always effective. My reason for thinking there is little combustion of the gases at 3 feet below the surface of the materials is, that when the vapours pass through the stove and reach the top of the stack, where they come in contact with the atmosphere, there bursts out a bluish flame, visible at night, which is speedily extinguished from a reduction of temperature below the point at which the mixed gases burn. When, on the contrary, I allow the materials in the furnace to fall below the mouths of the flues, a combustion of the gases takes place previous to entering the stove, and the vaporous appearance disappears. Looking at the perfect simplicity of the arrangement, I think I may warrantably boast that this plan is equal in simplicity and in cheapness to the supply of hot water from the boiler at the back of the kitchen grate.

Plate II., with the references, will explain the details of the arrangements at Ystalyfera.

a. Cross section through furnace and heating stove, showing—
b b. Flues from furnace to stoves.
c. Hot air chamber, containing—
d d. Upright hot air tubes.
e e. Stacks which create the draught and draw the gases through the flues *b b* into the hot air chamber.
f f. Dampers on stacks, to regulate the supply of heat from the furnaces into the hot air chambers.
g g. Cross pipes, on which the upright hot air tubes are fixed.
h h. Side pipes, conveying the blast to the cross pipes.
i i. Upcast pipes, conveying cold air to the stove.
j j. Downcast pipes, conveying heated air to the tuyères.
k k. Front doors, by opening which the draught is reversed, and the hot air chamber cooled down.
l l. Roofs over heating chambers.
m. Horizontal section of heating chambers and flues.
n. Vertical section through heating chamber and stack.

The plan thus described has several great advantages, some of which I did not at all foresee:—1st, it requires no coal or labour; 2nd, the blast is better heated and more regular; 3rd, the apparatus is more durable.

The pipes not being exposed to great and sudden changes of temperature, from being sometimes overfired, and at other times neglected, do not wear out rapidly: so well proved is this, that the first stove I erected and set to work on the 8th of November 1844, now three years and nine months ago, is in good repair; and I even think that a sort of cementation process takes place, so that the iron in the pipes becomes gradually so tough as to be nearly indestructible, whilst, according to the former plan of stoves, I never had a set to last twelve months, and although their construction and treatment may have been much improved, it is well known the repairs are still frequent and costly.

I will now notice some points which have always been felt as probable objections to this application by practical men.

First, as to the probability of the flues becoming choked. The flues, if built of fire-brick, and placed not lower than 3 feet from the furnace top, have no great tendency to clink, whilst any loose stuff collecting in the mouths can be readily removed by a rabble.

Secondly, as to the stove becoming full of dust. The quantity of dust that collects in a stove is not great, and until it accumulates very much is of no inconvenience, from there being such a surplus supply of heat at command. On the contrary, we think the deposit of dust in the stove rather a protection to the pipes, and we have gone on with a stove eighteen months without cleaning, which continued to give good hot-blast.

Thirdly, as to the supposed cooling of the blast during stoppage of the furnace. If a furnace stops from any cause, we lower the damper, and the stove is so closed in and full of heat, with so little of its surface exposed to cooling, that we have the blast hot within a few minutes of starting again; besides, we can always keep the damper up until the stove is in full heat, for ordinarily the damper is nearly close down on the top of the stack.

Fourthly, as to the difficulty of obtaining hot-blast in *blowing in* a furnace. As to starting a new furnace and a new stove, we put on a cold-blast load for the first day's melting, after which the stove gets dry and gives us hot-blast without further trouble. If the stove be of green masonry, I put a small drying fire into the stove at the door, and continue it until the draught acts readily through the flues. It happened to me in the first stove I erected that the damper was let down until the stove should have dried; the gas from the furnace collected until it attained the condensation and temperature requisite for explosion, which took place, blowing out the front of the stove. By the precaution of leaving the damper up, this cannot happen.

Fifthly, as to the means of cooling the stove, so as to have access to it. The mode in which this is effected is one of the most perfect parts of the whole arrangement: each stove has a door in front. If we want to cool down a stove so as to enter it, we let down the damper, which stops the draught from the furnace, and we open the front door, which admits a draught of cold air through the stove and flues into the furnace; we either wholly close the damper and open the door, or only partially so, if we think it best to reduce the temperature gradually, and we have never done any damage to a stove in cooling, which is far from being the case when the fire-bars are taken out from an ordinary stove-grate to cool it down; for it is a common saying that the cooling down of a stove to stop a leak, generally produces a dozen fresh ones.

There is however one point to be attended to, from neglect of which I had nearly made shipwreck of the plan.

Fortunately, I erected the first stove so low down the side of the furnace, that the point where the flues entered was much above the cross pipes; and

this arrangement worked well; but I thought it would be an improvement in building the next oven to raise the whole higher, which I did, so that the gross pipes were on a level with the mouths of the flues. The consequence of this alteration was, that as the cemented joints are never free from pin-hole leaks, the small jets of air that escape ignited the gases, working like so many small blowpipes, and caused an immense local temperature, so much so, as speedily to destroy the stove; I had however my first plan to fall back upon, which enabled me to correct this error, or it would probably have been fatal to the application; accordingly we lowered the apparatus, and had no more inconvenience. The remedy is easily explained; for by lowering the stove so as to have the cross and side pipes below the mouths of the flues, as the gases from their levity do not descend lower than the entrance into the stack, the joints are not placed in a combustible medium, but, on the contrary, the space below is probably filled with carbonic acid, the heavier gas, which being incapable of supporting combustion, any small leak of air there may be is of no importance whatever.

I have six furnaces at Ystalyfera, built in a row, and joined together by arches; on these arches five stoves are placed, which heat the blast for the six furnaces; each stove is consequently between two furnaces, and has flues conveying the heat from both. I have also a hot-blast main pipe, so that all the heated air is in a pipe common for all the furnaces. This is an excellent arrangement for any one erecting new works, but is not at all necessary to my plan, as I have No. 2 furnace working alone, with a stove on one side only, which heats the blast perfectly; indeed the means of heating the blast are so excessive of what is required, that any length or drop in the flues leading to the stove may be compensated for by an increased height of stack. The gaseous escape could I am now convinced be carried a great distance, and be equally effective as a heating medium, if preserved from access of air, and provided the temperature is kept up; if the flue is carried under ground, both these ends will be attained. I calculate that the cost of erecting a stove attached to a furnace on my plan, as compared with two or three stoves in the ordinary way, at the base of a furnace, is about one-third less in favour of my arrangement, as I have a much less weight of metal in the pipes, and a great deal less masonry to erect; the repairs are nothing. It will thus be seen that I take credit for having conquered a great practical difficulty, and for having made a useful and œconomical application of part of the gaseous escape from the furnaces at Ystalyfera.

To me the saving is important, which I calculate as follows, compared with the use of the ordinary heating ovens.

Thirty-three tons of anthracite coal saved a week of rubble size at 4s.					£6	12	0
Two men, and wheeling coal and ashes					2	0	0
					£8	12	0
per week, or	£447	4	0	per annum.			
Saving in repair of stove, say one-fifth of £500, the cost of new stoves	100	0	0				
	£547	0	0				

which on ten furnaces, the full extent of the works, would amount to £5470 a-year, or on five furnaces our present scale of work, to £2735 a-year. In the bituminous coal districts, where slack coal can be used for heating the stoves, the coal consumed would only be worth 2*s*. 6*d*. or 3*s*. per ton; but then such coal is very wasteful, and probably a greater quantity would be required than with anthracite, so as to make the expense of fuel equal.

The caution and reluctance to entertain or adopt alterations in any process of manufacture, is a safe and prudent feeling in those who manage manufacturing concerns, and I by no means complain of it, when applied to myself; but as time passes by, and the iron trade observes that my stoves do not wear out, that there are no stoppages for repair, that I use no coal or labour, and thus have the blast well-heated without any current cost, I expect that a greater degree of interest will be felt in my improvement. If of the 1,500,000 tons of iron made yearly in Great Britain, we assume that 1,000,000 tons are made by hot-blast in 200 furnaces, making 5000 tons a-year each, the saving of £500 a-year per furnace would be £100,000 a-year. This important amount will I hope soon be added to the profits of the iron trade, or at least be a reduction from its losses.

Having thus given an account of the use made of the gaseous escape from the blast furnaces at Ystalyfera, to heat the air by which they are blown, I will proceed to detail the further use made of the same plentiful and valuable, though hitherto neglected vapours, to raise the steam for the engine.

I stated that I do not consider that it requires one-sixth of the escape of a furnace to heat the blast in the stove; this sixth part does the work of from 30 to 35 tons of rubbly anthracite coal a week, burnt in the ordinary way in reverberatory furnaces. I was deterred until recently from applying any part of the other five-sixths going uselessly to waste, to the purpose of raising steam in the boilers, by the distance of the boilers from the furnaces. I feared that the heated vapours would be too much cooled down in the passage to the boilers, and that the draught would consequently be faint. However, on the approach of the meeting of the British Association, I resolved to make the attempt, to show the practical men who might attend it, that the long-neglected gaseous escape of a furnace would not only heat the blast, but without combustion raise the steam also in the boilers. For this purpose I prepared No. 9 furnace for blast, and as No. 8 furnace adjoining is out of blast, the whole result attained is the independent effect from No. 9 alone. To carry out my purpose, besides applying part of the escape from No. 9 to its hot-blast stove adjoining, I constructed two flues, 24 inches in diameter, leading into a main flue 32 inches in diameter, which is conducted into the tube of the nearest boiler, the distance from the furnace to the boiler being 46 feet. The tube of the boiler is divided by a brick partition into two compartments, and the heated vapours pass four times through and under the boiler, a total length of 120 feet. The boiler stack is 80 feet high and 6 feet in diameter, and creates an overpowering draught, which takes off the gases from the furnace, and fills the boiler with these heated vapours. Although from the length of the flue required, 46 feet, to conduct the vapour from No. 9 furnace to the boiler, during which it is exposed to the cooling of the atmosphere in its whole length, being carried on girders as a bridge, I consider that a considerable part, say above one-half of the heating effect, is lost as compared with that produced in the stoves, where the flues are under cover in masonry, and the whole is kept close, yet the success of the attempt has been beyond my expectations. The boiler raised double the steam it did when heated by coal, so that I am already in the enjoyment of a saving of 35 tons of coal a week on the boilers' use. I am preparing to carry the gaseous escape from two other furnaces to two other boilers, and in doing this I shall protect the flue from exposure to the air, which will I expect give me sufficient steam for the engine, and I have little doubt of saving the consumption of boiler coal altogether, except we use one boiler with a fire, in order to make a start in case of stoppage. I might perhaps have deferred the attempt, which I have long contemplated, to use the vapours from the furnace to raise steam, but for the visit of the British Association, and this rousing one to action is among

the many benefits such visits confer on a neighbourhood. The saving already effected by the application to one boiler is equal to £350 a-year, and the total saving of doing away with the use of coal in the boilers, and consequently with attendance, fire-bars, bricks, would at full work exceed £2000 a-year. The savings I have mentioned are so serious in amount, that they cannot safely be neglected by the iron trade.

But although I save the use of 35 tons of coal a week in the stoves, and 35 tons a week in one of the boilers by taking off a portion of the heated air from No. 9 furnace, and although the gas sent to the boiler wastes half its heat in the passage, there still remains one-half of the quantity usually escaping, passing off the tunnel head. If I closed the tunnel head of No. 9, so as to collect all the gases, it would therefore appear that I should obtain a heating power equal to the use of 140 tons of coal a week in air furnaces, and that merely by the passage of such gases through the boilers and stoves in contact with iron vessels, containing the water and air required to be heated. But as I only consume about 100 tons of coal a week in the No. 9 furnace, this is 40 tons more effect than the whole coal used, which melts besides from 150 to 160 tons of iron ores and limestone flux, and produces 50 or 60 tons of pig-iron a week, and all this while I have not consumed the gases, but merely received by contact with good conductors some part of the high temperature acquired in the furnace. What other inference can I draw but one, that a very large proportion of the fuel used in reverberatory furnaces is unprofitably wasted? for it would appear to be more profitable to employ a blast-furnace, if as a gas generator only, even if you smelted nothing in it, and carried off its heated vapours by flues to your boilers and stoves, than to employ a separate fire to each boiler and each stove. These considerations irresistibly suggest to me a great revolution in metallurgical practice; a new arrangement in fact of furnaces and works, by which considerably above one million a-year might be saved in the iron trade alone.

The following is the analysis of the gas escaping from the Ystalyfera anthracite furnaces made by Dr. Schafhaeutl.

First, of the gas taken off 16 feet below the surface of coal and mine in the furnace, he gave the following result:—

Carbonic acid	00·136
Carbonic oxide	18·974
Hydrogen	27·844
Light carburetted hydrogen	3·212
Sulphurous acid with traces of arseniuretted and phosphuretted hydrogen	trace
Nitrogen	49·844
	100·000

A very considerable change takes place when the gas has access to the atmosphere.

At 1 foot only below the surface of the coal and mine in the furnace, the following is his analysis:—

Carbonic acid	9·546
Carbonic oxide	12·012
Hydrogen	21·278
Light carburetted hydrogen	2·548
Sulphurous acid with traces of arseniuretted and phosphuretted hydrogen	0·111
Nitrogen	54·505
	100·000

From close observation, I think at about 3 feet below the surface of the materials, which is the point where I draw off my supply from the furnace, very little combustion has taken place, and that the gases remain pretty much as they were in the bowels of the furnace. We observe, that as the gases rising from the furnace come in contact with the atmosphere, the whole burst out into a spontaneous flame, and it is my object to take them off at a point, where from the cover of the materials they are protected from this combustion, and this from practice I find to be about 3 feet down. The large quantity of hydrogen in the analysis is puzzling, as anthracite coal only contains 2 or 3 per cent., and certainly the flame from an anthracite furnace, seen at night, is very different in colour from that escaping from furnaces using bituminous coal, the flame being of a bluish-white colour, and not at all yellow. The absence of carbonic acid in the first analysis, and its presence in the second, proves that the solid carbon of the fuel, after having been converted at the tuyères into carbonic acid gas, by combustion with the oxygen of the blast, passing upwards into the middle region of the furnace, where carbon is in excess, absorbs an additional dose of it, and is thereby converted into carbonic oxide, a combustible gas ; and the whole gaseous escape of the furnace, before the access of the atmosphere, appears to consist of about 50 per cent. of highly inflammable gases and 50 per cent. of nitrogen, incombustible, but heated to a very high temperature. What use shall then be made of this great escape of combustible gas, after using it, as I do, as a mere heating medium ? The passage through the boilers and stoves, where this heating effect is given, and where all access of atmospheric air is carefully prevented, would in no way interfere, under proper arrangements, with its subsequent use as a highly combustible gas in a suitable furnace.

In reverberatory furnaces everything depends upon a good draught being maintained, so that, although the chimneys may be full of combustible gases, as we plainly see they are at night when passing the copper works, yet nothing can be done to arrest them, they must pass off freely, so that a full supply of air may be drawn through the fire-grate ; this difficulty will always be a great obstacle to the curing of coal smoke, or to the condensation of metallic vapours passing off therewith over the bridge. But this does not at all apply to the blast-furnace ; nothing there depends on draught, but everything on the power of the steam-engine to force a column of air through 40 feet of dense materials. The combustible gases passing over a reverberatory furnace speedily combine in the stack with a fresh dose of oxygen, and become useless, whilst on the contrary, the carbonic acid resulting from combustion at the tuyères in a blast-furnace, meeting with an excess of carbon, becomes again a combustible gas, as carbonic oxide.

It therefore appears that the whole of the present arrangements of an iron works ought to be reversed, that the steam-engines and boilers for the blast, and for the forge and mill, should be on a platform above the back wall, the stoves being alongside the furnaces ; the steam should be raised in the boilers, and the air heated in the stoves, by the mere passage of the gases from the gas generator (the furnace) towards the gas furnaces, in which the refinery, boiling, puddling and balling processes necessary to convert pig into malleable iron, should be performed. If the whole of the solid carbon put into the furnace be present at the tunnel head as carbonic oxide, requiring another dose of oxygen for saturation, and giving thereby a further production of heat, its entire combustion would without doubt, in gas furnaces, be amply sufficient for the mill and forge purposes. There is, besides, the hydrogen of the fuel, which from its volatile nature never reaches the tuyères, and performs no useful part in a blast-furnace, but which would then be fully em-

ployed, and from its igniting at a lower temperature, greatly assist in the operations of the gas furnace; and therefore I believe the fuel put into the blast-furnace would, with such arrangements, not only by the combustion of its solid part, at and near the tuyères, smelt the pig-iron from the ore, but by the mere passage of these vapours, heat the blast, raise the steam, and finally, by the entire combustion of the gases, supply fuel for the forge and mill, and thus complete the whole conversion from the ores to malleable iron, by the consumption of about 2 tons of fuel, instead of using 6 tons or thereabouts as at present. It cannot be doubted that the air-furnace is a most imperfect instrument in metallurgy: a large proportion of the fuel is unprofitably converted therein into combustible gases, which pass unburnt out of the chimney. It requires indeed a very large drawback from the effect of the fuel used in air-furnaces, to account for how I have attained such superior results, by merely passing one-half of the gaseous escape unconsumed through a boiler on one side of my No. 9 furnace, and through a heating stove on the other. The difficulty that would remain in carrying out fully the utilization of the whole power of the fuel put into the furnace, would be the management of the gas-furnace. I regret I have not had opportunities of personally witnessing the use of gas-furnaces, consuming the escape from blast-furnaces, for the purposes of the processes of the forge and mill, such being only practised abroad, where the dearness of fuel has induced persistence and perseverance in the application; I have however witnessed a gas-furnace in successful operation at Ynyscedwyn, under the direction of the patentee, Mr. Detmold. In this case, the gas was not however derived from the blast-furnace, but was generated in a sort of double furnace, in which the combustible gases are generated by a blast of air injected into the ash-pit, whence it passes through the coal in the grate, whilst the combustible gases thus produced are consumed by forcing amidst them in their passage over the fire-bridge, heated and compressed atmospheric air supplied in numerous small streams.

Mr. Detmold had successfully introduced this description of furnace for forge and mill purposes into the anthracite districts of the United States, where from a deficiency of flame this fuel could not be used for boiling and puddling in the usual reverberatory furnaces, and he came over to this country to introduce his improvements here. The gas-furnace tried at Ynyscedwyn was for the purpose of refining pig-iron, or converting it into what is technically called metal, it being a desideratum to refine with anthracite coal, which from its great density we are unable to do. The heat produced was very great, yet by means of water-breasts, and other contrivances, the furnace stood pretty well. The iron was speedily converted into metal, which proved on trial to be of good quality; and the loss of yield was much less than in the refinery process at present used; but the metal had a dull appearance instead of the silvery appearance, by which its good quality is generally judged; and as a greater part of the anthracite metal is exported to distant markets abroad, this difficulty caused the process not to be pursued. It appears to me probable, from the difficulty there will be to use anthracite coal in puddling, boiling and balling, on account of the absence therein of the constituents that make the protecting flame necessary in these processes in reverberatory furnaces, that the gas-furnace will be introduced into use in this country in the anthracite districts, when the manufacturers of iron with this fuel feel the necessity of extending beyond the make of pig-iron. I may therefore, at some subsequent meeting of the British Association, have to detail the results of this application at Ystalyfera. At present, I shall carefully proceed to apply the heating power of the gaseous escape fully to the boilers, as I have done to the stoves, and shall also endeavour to calcine the mines in the same

way, so as to reduce the expenditure of fuel to that which takes place in the blast-furnace. Proceeding cautiously and in a commercial spirit, I do not despair of so combining profit with experiment, as in practice to show the example of the final œconomy I have pointed out, namely, that for less than 2 tons of coal put into the furnace, I shall complete the manufacture from the ores to malleable iron, thus œconomizing two-thirds of the coal used in the iron manufacture in this country.

If the result I have pointed to is ever arrived at, as I believe it may be, that the whole process from the ore to the malleable iron be completed and achieved by the coal put into the furnace, for the purpose only, according to present practice, of reducing the iron from its ores, the saving of fuel in the manufacture of iron in Great Britain will not be less than 5,000,000 tons a year, worth considerably more than £1,000,000 sterling. Thus the blast-furnace would come to be considered, not merely as a smelting-furnace for the reduction of ores and metals, but as a gas generator, the source whence was to be drawn all the heat necessary for all the subsequent processes. I will not indulge myself further in speculating on the great revolution so vast an œconomy would produce, but will content myself with the hope that my observations will be received with indulgence, as I wish to divest them of all pretensions. My practice makes the first part of my subject sure; and in speculating on the further use of the gases passing off from our blast-furnaces as a substitute for coal in the subsequent processes of converting pig into malleable iron, I have followed the lead and indication which the facts I have arrived at obviously offer. I hope my notice of the subject will attract the attention of those in the iron trade more competent than I am to pursue it to a satisfactory result; and I am content to place my views on record as those of one who is convinced that the prosperity of the iron trade depends on the œconomy of its processes, and that in fact its profits must be made out of its savings.

Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations. By ROBERT HUNT.

THIS investigation was assigned to the charge of a committee, and two sets of experiments have been established, one by Dr. Daubeny at Oxford, and the other by Mr. Hunt in London, upon ferns which have been supplied from the Royal Botanic Gardens at Kew. The arrangements are such, that two sets of these plants, belonging to the same class, are made to grow under the same circumstances, except that one set is supplied with measured quantities of carbonic acid. Numerous preliminary experiments had to be made, and several sets of plants have been destroyed in the progress of these. No general result can be announced beyond the fact, that the plants, by being gradually inured to the agency of the carbonic acid, can be made to bear a greater quantity than when a large per-centage is given to them at once. The experiments must be continued over a long period before we can arrive at any decided result.

Supplement to the Temperature Tables printed in the Report of the British Association for 1847. By Professor H. W. DOVE, *Cor. Memb. of the British Association; containing* 84 *additional Stations.*

1. Arctic Regions.—Mean Temperature of each Month, each Season, and the whole Year.

	Lat. N.	Long. W.	Elev.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Winter.	Spring.	Sum.	Aut.	Year.	Diff. H. & C. months.	Diff. S. & W.	No. of Years.	Hour of observation.	
	° ′	° ′	Feet.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°			
Fort Enterprise	64 28	113 6	850	−15·6	−25·3	−11·6	4·6	31·6	..	..	..	33·8	23·4	−0·7	−29·6	−23·50	8·20	..	18·83						
Iluluk	53 52	166 25	..	34·27	32·47	31·82	34·16	39·25	44·98	49·55	54·82	54·07	42·73	35·17	33·94	33·56	35·08	49·78	37·32	38·94	23·00	16·22	1¾	8, 1, 9	D.
Kotzebue Sound	68 0	163 0	..	..	..	..	..	..	..	52·33	43·	34·04	..	..	..	..	..	..	..	..	..	..	¼	dail. extr.	D.
Neu Hernhut	64 10	52 40	..	9·05	22·10	21·65	24·80	32·00	40·10	40·33	37·40	34·03	32·90	15·80	11·75	14·30	26·15	39·28	26·50	26·83	31·28	24·48	1	....	D.
Fort Simpson	62 11	121 32	250	−13·46	−10·43	4·47	25·94	47·89	63·50	60·81	53·16	48·00	23·20	7·52	−9·22	−11·04	26·10	59·16	26·24	25·12	76·96	70·20	2⅛	8, 2	D.
2. United States and Canada.																									
Anahuac	29 0	94 0	..	..	..	60·35	69·13	74·98	80·38	84·61	80·60	78·80	..	..	..	.	68·15	81·85	..	..	..	..	⅓	....	a.
Boston	42 21	71 4	..	26·56	27·78	35·79	45·85	56·63	65·96	71·98	69·19	60·77	50·88	39·72	30·52	28·29	46·09	69·04	50·46	48·47	45·42	40·75	20	sunr. 2, 3, 10	D.
F. Crawford	43 3	90 52	575	19·72	21·93	32·48	43·92	59·45	68·57	72·40	71·41	60·50	45·45	33·06	18·04	19·90	45·28	70·79	46·67	45·66	54·36	50·89	2	7, 2, 9	D.
Flatbush	40 40	74 6	..	27·09	35·24	41·05	52·17	58·77	65·80	72·10	70·51	64·51	55·02	38·98	37·68	33·34	50·66	69·47	52·71	51·55	45·01	36·13	2	....	b.
Fredericton	45 57	66 45	..	17·	24·	33·	40·	37·	48·5	65·5	69·75	61·5	47·5	31·	13·5	18·17	36·67	61·25	46·67	40·69	56·25	43·08	..	....	c.
Germantown	40 3	75 10	..	30·	33·1	41·2	49·4	61·3	71·2	75·	73·	65·	53·5	42·6	32·6	31·90	50·63	73·07	53·67	69·76	45·00	41·17	9	....	d.
New Harmony	38 11	87 45	340	34·11	41·53	52·56	56·04	67·64	76·36	78·85	75·50	65·65	55·72	43·27	37·26	37·67	58·75	76·90	54·88	59·05	44·74	39·23	2½	....	e.
Huntington	40 52	73 80	..	26·	29·	24·	49·	63·	65·	75·	71·	69·	54·	42·	31·	28·67	45·33	70·33	55·01	49·83	51·00	41·66	..	....	f.
Hunt's Ville	34 36	86 57	..	51·	53·	50·	63·	69·	81·	81·	79·	76·	62·	58·	42·	48·67	60·67	80·33	65·33	63·75	39·00	31·66	1	7, 2, 9	D.
Ogdensburgh	44 43	75 33	225	24·75	12·33	32·94	39·81	52·54	66·53	71·66	68·31	59·22	44·58	29·74	19·43	18·84	41·76	68·83	44·51	43·49	59·33	49·99	1	N.Y.	D.
Richmond	37 4	77 31	..	33·7	39·8	47·1	54·7	65·4	73·8	77·6	74·8	67·1	57·5	44·2	38·1	37·20	55·73	75·40	56·27	56·15	43·90	38·20	4	....	g.
Schenectady	42 48	73 55	..	21·20	22·10	31·24	45·33	57·89	66·47	70·38	67·48	59·68	48·01	37·82	26·86	23·59	44·82	68·11	48·50	46·26	49·18	44·52	5	N.S.	D.
3. Mexico and the West Indies.																									
Caracas	10 31	67 5	..	69·72	69·98	70·25	71·66	73·04	72·30	73·53	73·40	72·73	73·00	72·39	69·44	69·71	71·68	73·08	72·71	71·76	4·09	3·37	1	dail. extr.	h.
La Guayra	10 37	67 7	100	76·59	76·51	77·42	78·45	79·42	79·78	79·30	80·70	81·12	80·69	79·64	76·81	76·64	78·43	79·93	80·48	78·87	4·61	3·84	1	6, 11, 4, 9	h.
Tovar	10 31	67 30	5300	61·52	62·65	64·06	64·90	64·90	65·35	65·75	65·75	66·02	64·63	64·63	63·05	62·41	64·6[illegible]	65·62	65·09	64·44	4·50	3·21	1	dail. extr.	h.
4. South America.																									
Monte Video	−34 54	56 13	..	80·	77·	74·	72·	58·	56·	57·	59·	58·	66·	70·	75·	77·33	68·	57·33	64·77	66·83	24·	20·	1	....	i.
Port Egmont	−51 20	60 0	..	54·10	54·21	51·60	48·63	46·63	43·48	37·47	38·62	45·73	47·50	47·19	49·87	52·73	18·95	39·86	46·81	47·09	16·74	12·87	1	12	k.
?	−41 0	−174 0	..	57·3	60·0	55·0	65·7	50·0	45·5	42·3	45·5	48·0	53·5	..	..	..	53·70	44·43	..	..	17·7	..	[illegible]	9	l.
6. Great Britain and adjacent Islands.																									
Anatomical Garden	56 24	..	..	36·6	39·5	40·6	45·5	51·5	57·2	60·6	58·2	54·5	48·8	43·2	39·9	38·67	45·87	58·67	48·83	48·01	24·	20·	7	10, 10	D.
St. Bathans	55 52	2 23	420	34·	37·1	32·6	37·2	45·3	53·9	57·	54·5	50·2	47·6	38·3	39·6	36·90	38·37	55·13	45·37	43·94	24·40	18·23	1	10, 10	D.
St. Helers	49 11	2 6	..	43·83	41·67	42·93	49·90	52·10	62·10	62·87	61·53	61·17	54·17	48·30	42·25	42·58	48·31	62·17	54·55	51·90	21·20	19·59	3⅛	9, 2, 5, 8, 11, 12	m.
Kinfaun's Castle	56 23	3 19	140	35·99	38·17	40·70	44·85	50·30	55·81	58·45	57·39	53·43	47·13	41·79	38·66	37·61	45·28	57·22	47·45	46·89	22·46	19·61	22	dail. extr.	D.
Northumberland	..	..	..	35·57	38·95	39·94	44·09	49·89	56·20	58·47	57·44	54·44	45·83	42·66	36·73	37·08	44·64	57·37	47·64	46·68	22·90	20·29	7	9, 2, 11	D.
Plymouth	50 22	4 7	..	44·16	44·83	45·60	48·53	54·92	58·88	62·01	61·80	57·79	52·72	48·15	45·14	44·88	49·68	60·87	52·91	52·08	17·85	15·99	5	hourly	D.
Swafham Balbek	..	..	..	42·98	43·97	43·79	47·50	55·15	64·99	65·64	65·50	60·01	51·06	45·57	31·19	37·38	48·81	65·38	52·21	41·45	34·45	21·	1	dail. extr.	n.
Thornshavn, Faroe I.	62 6	6 46	..	37·56	36·90	37·52	41·81	45·37	53·44	55·87	54·55	51·50	45·95	41·69	42·63	39·03	41·57	54·62	46·38	45·40	18·97	15·59	..	....	D.
7. France and Switzerland.																									
Nancy	48 41	−6 11	800	33·26	37·47	41·47	49·21	56·21	62·80	63·46	62·15	59·54	49·28	41·99	34·86	35·20	48·96	62·80	50·27	65·74	30·20	27·60	6	dail. extr.	o.
Nismes	43 51	−4 21	..	39·43	44·38	53·83	59·45	69·35	71·83	78·80	78·58	69·80	61·94	50·68	45·05	42·95	60·88	76·40	60·80	60·26	39·37	33·45	3	morn. even.	p.
St. Galle	47 26	−10 22	1700	29·03	33·69	40·10	48·97	56·21	60·82	65·39	67·37	58·21	48·85	39·58	33·67	32·13	48·43	64·53	48·88	48·49	38·34	32·40	16	9, 9	D.
Rolle	50 3	−5 4	..	32·00	37·40	38·12	44·97	57·47	61·88	68·54	66·38	60·62	50·18	40·46	35·6[illegible]	35·	46·85	65·60	50·42	49·47	36·54	30·60	1	....	q.
17. India and China. Africa.																									
Pekin	39 54	−116 26	..	24·71	31·01	41·81	57·56	67·17	73·36	76·30	75·85	67·64	54·30	40·73	28·96	28·23	55·51	75·17	54·22	53·28	51·59	46·94	4	5–9 hourly	r.
Trevandrum	8 31	−74 50	..	78·06	79·63	81·66	82·70	81·48	78·60	78·10	78·28	78·47	78·47	77·67	78·10	78·60	81·95	78·33	78·20	79·27	5·03	−0·27	8½	hourly	s.
St. Denis	−20 51	−55 30	..	79·72	80·74	80·11	78·10	76·08	73·72	71·80	72·57	75·16	76·81	78·55	79·59	80·02	78·10	72·70	76·84	76·91	8·94	7·32	2	sunr. 2	t.
Gondar	12 36	−37 31	6964	65·77	67·98	70·32	70·84	..	..	..	..	..	64·72	64·67	63·07	65·91	..	..	..	..	..	..	½	5½, 12½	u.
"	13 6	−38 20	9713	..	..	..	..	..	52·72	52·59	53·47	..	..	..	..	..	..	52·93	..	..	..	..	⅓	5½, 12½	u.
"	15 36	−35 56	..	77·86	79·48	82·47	85·42	98·91	98·49	..	..	92·75	89·87	85·91	82·00	79·78	89·07	..	89·51	..	21·05	..	⅜	5½, 12½	u.
Mocha	13 20	−50 54	..	..	..	..	..	..	89·14	90·73	..	..	..	..	..	..	..	..	..	..	..	..	..	9	x.

a. A Visit to Texas.
b. Picture of New York.
c. Montg p. 236.
d. Darby, Unit. St. p. 394.
e. Darby, Unit. St. p. 403.
f. Sketch of Long Island.
g. Darby, Unit. St.
h. MS.
i. Freycinet, Voyage, 1333.
k. Ibid. 1289.
l. Westminster Rev. 1847, p. 488.
m. Rep. Brit. Assoc. 1844, p. 14.
n. Quetelet, Phenom. Period. 20, p. 50.
o. Mém. de Nancy.
p. Laurent, Nismes, p. 216.
q. Quetelet, Climat de Belgique, p. 93.
r. Annuaire de Russie.
s. MS.
t. Thomas, Statistique de Bourbon.
u. Rüppel, Reisen nach Abyssinien, and Voyage en Abys.
x. Héricourt, Voy. de Cheri.

	Lat. N.	Long. W.	Elev.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Winter.	Spring.	Sum.	Aut.	Year.	Diff. H. & C. months.	Diff. S. & W.	No. of Years.	Hour of observation.	
	° ′	° ′	Feet.	°	°	°	°	°	°	°	°	°	°	°	°		°	°	°	°	°	°			
enedictbeurn	47 42	−11 30	..	25·97	34·75	30·36	50·20	61·25	59·59	65·68	63·70	52·16	43·90	34·36	29·79	30·17	47·27	62·90	43·47	45·98	38·18	32·82	1	7, 2, 9	D.
reslau	51 7	−17 2	373	27·88	29·14	34·90	45·73	56·55	63·10	65·30	62·42	58·48	48·58	38·19	30·56	29·19	45·73	63·61	48·42	46·74	37·42	34·42	9	6, 9, 12, 3, 9	D.
oblenz	50 22	− 7 36	200	32·72	36·50	43·34	52·70	59·54	64·94	68·36	66·56	60·26	51·98	42·98	37·76	35·66	51·86	66·62	51·74	51·47	35·64	30·96	16		D.
ronberg	50 12	− 8 30	..	31·23	40·34	43·03	51·37	57·52	62·49	66·20	74·05	59·74	52·57	36·97	35·67	35·75	50·64	67·58	49·76	50·93	42·82	31·83	1, red. M.	red.	*a.*
denkoben	49 17	− 8 6	..	33·24	37·29	47·01	52·79	61·41	64·63	67·66	67·93	60·80	51·46	42·91	40·26	36·93	53·74	66·07	51·72	52·12	34·69	29·14	1, red. M.		*b.*
isleben	51 33	−11 30	386	26·31	30·65	41·14	48·43	55·74	60·26	63·75	62·65	57·34	48·70	49·20	33·40	30·12	48·44	62·22	51·75	43·13	37·44	32·10	10		*c.*
lberfeld	51 15	− 7 10	372	34·23	37·42	41·47	50·02	56·75	61·93	64·60	62·71	58·35	51·17	43·18	38·17	36·61	49·41	63·08	50·90	50·00	30·37	26·47	12	8, 2, 8	D.
rlbach	49 32	−10 28	..	29·88	32·25	43·30	52·61	57·54	62·44	65·14	64·18	59·81	48·99	36·66	[illegible]	31·95	51·15	63·92	48·49	48·63	35·26	31·97	1, red. M.	red.	*d.*
reiberg	50 55	−13 20	1232	28·17	33·01	38·35	48·43	57·83	64·83	67·30	65·80	58·51	50·34	36·86	31·32	30·83	48·20	65·98	48·57	48·37	39·13	35·15	9	9, 12, 3	D.
latz	50 26	−17 0	960	29·14	40·71	34·32	46·31	51·91	58·93	62·60	63·46	53·08	47·14	39·04	35·56	35·14	44·18	61·66	46·42	46·85	31·32	26·52	1	7, 2, 9	*e.*
ottersdorf	..	..	..	29·10	34·88	35·35	39·88	57·43	63·41	59·79	61·81	52·00	43·29	32·65	27·90	30·29	44·22	61·67	42·65	44·71	35·51	31·38	1	7, 2, 9	D.
oethen	51 45	−11 57	..	28·67	32·63	38·03	46·96	55·99	62·13	65·23	64·56	58·33	49·51	40·01	35·13	32·14	46·99	63·97	49·28	48·09	36·56	31·83	21		*f.*
reuzburg	50 59	−18 12	617	31·62	41·68	35·83	45·73	51·37	60·53	63·55	64·15	52·45	47·05	35·71	34·86	36·05	44·31	62·74	45·07	47·04	32·53	26·69	1	6, 2, 10	*e.*
rumau	48 49	−16 39	1596	27·23	31·05	36·91	44·31	54·97	62·49	64·09	62·56	56·68	47·77	36·77	30·20	29·49	45·40	63·05	47·07	46·25	36·86	33·56	9	2–3	D.
upferberg	50 53	−16 58	1608	28·02	37·90	33·22	43·99	48·90	56·48	59·23	59·83	50·81	45·19	37·58	32·86	32·93	42·04	58·51	44·53	44·37	31·81	25·58	1	7, 2, 9	*e.*
andshut	50 47	−16 3	1399	27·57	34·54	31·32	50·52	51·06	52·14	62·69	62·83	50·83	45·43	37·56	34·41	32·17	44·30	59·22	44·61	45·08	35·12	27·05	1	7, 1, 10	*e.*
andshut	48 33	−12 10	..	26·91	34·09	39·90	49·57	54·75	59·77	63·01	62·92	58·64	41·77	38·32	33·91	31·64	48·07	61·73	46·74	46·92	36·10	30·09	1, red. M.		*g.*
eobschutz	50 12	−17 49	1009	30·38	41·05	33·44	46·13	51·85	59·68	62·74	63·39	52·43	47·66	37·42	36·64	36·02	43·81	61·94	45·84	46·90	33·01	25·92	1	6, 2, 9	*e.*
iegnitz	51 13	−16 10	373	32·07	39·38	35·40	48·02	52·86	61·70	64·90	65·71	55·58	48·79	39·70	39·20	36·88	45·43	64·10	48·02	48·61	32·83	27·22	1	6, 2, 10	*e.*
leiningen	50 40	−10 30	..	31·73	37·13	40·89	46·36	52·48	63·77	64·76	[illegible]	54·95	48·02	43·72	28·96	32·61	46·58	63·46	48·90	47·89	35·80	[illegible]	1⅔	6, 10, 1, 6, 10, red.	*h.*
littenwald	47 27	−11 15	2880	27·05	32·25	34·84	42·98	52·50	60·04	60·26	59·50	54·19	44·87	37·90	32·63	30·64	43·44	59·93	45·65	44·92	33·21	29·29	8		D.
leisse	50 28	−17 20	570	31·46	41·54	34·75	46·67	51·80	59·79	63·48	64·14	54·23	49·06	39·49	37·85	36·95	44·41	62·44	47·59	47·85	32·58	25·49	1	6, 2, 10	*e.*
ppeln	50 37	−17 57	470	29·10	40·21	33·60	50·29	56·80	..	68·43	69·69	57·09	47·75	37·65	37·58	35·63	46·90	67·78	47·50	49·45	40·59	32·15	1	6, 12, 9	*e.*
less	49 59	−19 0	..	25·86	20·75	39·04	50·41	57·81	64·99	67·35	62·42	56·37	47·77	35·78	35·24	30·62	49·09	64·93	46·64	47·82	46·60	34·31	2		D.
atibor	50 22	−17 6	664	25·92	27·27	34·16	47·91	57·49	64·02	..	61·41	59·11	51·67	42·19	23·18	25·40	46·52	..	50·99	..	..	..	1	7, 12, 9	*e.*
11, 12. ITALY, SPAIN, COAST of the MEDITERRANEAN.																									
respano	45 0	..	1000	35·76	36·19	43·66	51·70	61·36	65·38	70·32	69·62	63·66	53·44	45·28	37·56	36·50	52·24	68·44	54·13	52·83	34·56	31·94	6		*i.*
larostica	43 50	..	..	38·59	37·49	47·59	55·99	65·50	70·27	74·53	72·79	68·35	58·48	48·67	41·28	39·12	56·36	72·40	58·50	56·59	37·04	33·28	7		*k.*
t. Jean de Maurienne	45 18	− 6 17	1700	30·51	34·23	42·58	49·42	58·15	63·73	67·78	65·71	58·55	50·86	39·49	32·52	32·45	50·05	65·74	49·63	49·47	37·27	32·29	12	2–3	D.
arcelona	41 23	− 2 12	204	48·74	51·44	55·04	59·90	66·20	73·40	78·80	78·80	72·86	64·76	55·94	50·36	50·18	60·37	77·00	64·51	63·03	30·06	26·82	54		D.
lalta	35 54	−14 34	..	57·10	59·07	..	63·50	69·73	70·36	78·00	..	75·74	70·05	61·34	58·00	58·06	..	..	69·04	..	20·90	..	1	12	*l.*
onian Islands	38 0	−21 0	..	..	..	..	63·27	70·12	72·93	77·23	80·50	..	63·27	..	..	..	..	76·89	..	..	..	..	½	12	*l.*
lexandria	31 13	−29 48	..	65·75	63·50	65·19	68·56	74·19	79·25	..	..	..	..	69·69	64·05	64·43	69·31	..	..	..	..	..	⅜		
	26 0	−33 40	..	63·38	69·44	80·38	81·79	92·19	90·50	94·44	91·66	86·56	81·50	69·13	61·81	64·54	84·79	92·02	79·06	80·10	32·63	27·48	1		
14. DENMARK, NORWAY, SWEDEN.																									
öteborg	57 41	−11 56	..	29·97	30·11	34·16	43·84	53·02	61·03	63·19	62·29	55·90	48·67	38·64	34·41	31·50	43·67	62·17	47·74	46·27	33·22	30·67	45		*m.*
loffmannsgave	55 0	−10 0	..	23·56	28·14	35·44	43·48	54·91	60·96	62·89	64·31	58·69	51·53	45·01	38·14	30·15	44·61	62·72	51·74	47·31	40·75	32·57	1	9, 2	*n.*
und	55 42	−13 11	60	28·49	29·07	32·38	41·29	51·71	60·33	63·25	62·65	56·19	47·01	37·92	31·50	29·69	41·79	62·08	47·04	45·15	34·76	32·39	50	Morn. 12	D.
lestersund	63 24	..	..	9·32	15·26	25·70	33·08	43·34	54·50	57·92	55·94	45·14	39·38	29·12	21·02	15·20	34·04	56·12	37·88	35·81	48·60	40·92	6		*m.*
raestoe	55 2	−12 3	..	29·70	32·02	35·17	43·81	52·12	59·14	62·15	62·29	56·59	49·62	40·75	32·56	31·43	43·70	61·19	48·99	46·33	32·59	29·76	10	red.	*o.*
öndmór	62 30	− 6 20	..	23·94	29·48	33·51	37·49	46·47	53·38	57·72	57·00	52·25	42·51	36·50	27·88	27·10	39·16	56·03	43·75	41·51	33·78	28·93	19		*p.*
orneo	66 24	−23 47	..	3·40	7·18	15·55	26·91	41·02	55·81	61·39	56·48	46·27	32·38	17·64	8·64	6·41	27·83	57·89	32·10	31·06	57·99	51·48	31		D.
15. RUSSIA.																									
arlö	65 0	−24 40	..	11·84	14·63	21·94	33·26	43·90	56·37	63·34	59·23	49·48	38·53	26·64	17·82	14·76	33·04	59·65	38·21	36·41	51·50	44·89	20	6, 12, 6	D.
esert of Kirgis	50 0	−60 0	..	− 2·97	−10·62	12·65	..	..	67·55	63·70	..	..	..	..	−13·02	− 8·87	..	..	..	..	80·57	..	¼		D.
ischney Tugilsk	57 56	−60 8	..	6·91	6·03	20·03	35·20	51·49	65·77	70·29	61·68	51·08	31·62	16·16	1·17	4·70	35·57	65·91	32·95	34·78	69·12	61·21	2	8, 3, 8	D.
yschminsk	57 0	−75 50	..	1·74	9·84	15·71	36·34	50·38	66·88	59·72	58·37	50·23	34·66	8·82	14·45	8·67	34·14	61·66	31·23	33·94	65·14	52·99	1	7, 2, 9	D.
oliskamsk	59 36	−56 50	..	− 2·00	8·60	32·61	42·80	49·39	61·99	58·10	50·79	45·21	27·21	− 3·39	10·11	5·57	41·60	56·96	23·01	31·79	65·38	51·39	1	2–3	D.
licimo Utkinsk	57 45	−59 22	..	− 2·09	2·66	22·96	33·62	49·46	62·62	73·90	59·20	50·88	28·92	7·83	− 6·93	− 2·12	35·35	65·24	29·21	31·92	80·83	67·36	1		D.

a. Lamont, 1843, 3, p. 159.
b. Ibid. 1842, 3, p. 57.
c. Lüdde.
d. Lamont, Ann. 1842, 3, p. 49.
e. Arbeiten d. Schlesischen Geselsch. 1845.
f. MS.
g. Lamont, Ann. 1842, 3, p. 55.
h. MS.
i. Schouw, Climat de l'Ital. p. 96.
k. Ibid. p. 113.
l. Edinb. Journ. 1828, p. 243.
m. Forsell, Swer.
n. Tidskr. for Natur. 3, 4.
o. Schouw, Veirligets Tilstand.
p. V. Buch, Can. Ins.

Remarks by Professor Dove *on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them: with an introductory Notice by* Lieut.-Col. Edward Sabine, *Gen. Sec.*

[The report of the British Association for 1847 contained a communication from Professor Dove of the mean temperature in Fahrenheit's scale of every month of the year at above 800 stations on the globe, to which he has since added in the volume for 1848 a supplemental list of 84 stations. From the materials thus collected and combined Professor Dove has constructed maps of the isothermal lines over the whole surface of the globe for every month of the year, which maps have been partly engraved and partly lithographed at the expense of the Royal Academy of Sciences at Berlin. The Association has received from Professor Dove the very liberal offer of a supply of any number of copies of these maps that may be desired, at no other cost than that of the paper and of taking off the impressions. This offer having been received since the meeting of the Association at Swansea, the Council, who in the intervals between the meetings act on behalf of the General Committee, have directed that 500 copies of the plates,—which it is understood will be three in number, one containing the isothermals for January and July contrasted, as being the months of greatest dissimilarity, and the other two containing the isothermals of each of the twelve months separately represented,—should be asked for, for the purpose of being offered to the members of the Association at a price which should merely cover their cost. It is expected that these copies will be received in England and be ready for distribution by the time of the Birmingham Meeting.

In part fulfilment of Professor Dove's promise to lay before the British Association a notice of some of the more interesting conclusions in regard to climatology, to which he has been led by this extensive generalisation, he has communicated the following paper (written in German and translated by Mrs. Sabine), which the Council have directed to be inserted in the annual volume, as a supplemental report to the one printed in the volume for 1847; and they have also directed that a sufficient number of additional impressions should be struck off to furnish copies to accompany the maps.

Edward Sabine,
General Secretary.]

Professor Dove's *Supplemental Report.*

The preliminary works on which these maps are based, are printed in the Transactions of the Berlin Academy. They treat of the elimination of the non-periodic and periodic variations of the temperature.

The temperature of any particular month varies very much in different years; its true value can therefore only be concluded from observations during a long series of years, and we possess such for so few places, that if we were to limit ourselves exclusively to them, the points through which the isothermals are drawn would be too few in number. It was therefore necessary to find some means of correcting observations which extend over only a few years, so that they might be in some degree equivalent to conclusions drawn from a longer period. This would be impossible if the variations in different years were local in a very restricted sense, and an inquiry into this point was therefore the first thing required. The thermic march of the weather during an interval of 115 years, from 1729 to 1843 inclusive, was sought to be determined in four memoirs on the non-periodic variations of temperature on the earth's surface; this was done by forming tables of contemporaneous series of observations for a considerable number of years, and dedu-

cing the variations of the months in single years from the means of the same months drawn from many years. It thence appeared that important variations are never merely local, but that the same character of weather prevails over large portions of the globe; that the anomaly reaches its maximum in one spot, in receding from which it lessens more and more, until, passing through places where the thermic conditions are in their normal state, an opposite extreme is reached, which so compensates the first, that the general sum of warmth distributed over the earth at any particular time of year is the same in different years, although the values which make up the sum may be very different. Knowing the prevailing character of the weather in particular places in the different years, we are enabled to deduce from the deviations at a few normal stations, where the observations extend over a long series of years, the quantitative corrections to be applied to the results of observations continued for only a few years. The fourth memoir contains the corrections calculated for nineteen such normal stations:—Madras, Palermo, Milan, Geneva, Vienna, Regensburg, Stuttgard, Carlsruhe, Berlin, Copenhagen, Torneo, London, Kinfauns Castle, Zwanenburg, Paris, Salem, Albany, Gothaab and Reykiavig. These four memoirs also contain the complete data derived from observations at 700 stations; or the *monthly means* during the respective years of observation.

The second necessary correction is that required for eliminating the diurnal variation, and reducing the observations made at particular hours to the mean of the whole twenty-four hours, as it is only at a few stations that observations were made hourly. These latter stations, twenty-nine in number, supply the values required to reduce the observations at any particular hour to the mean of the twenty-four hours, and are given in the memoir entitled "On the Diurnal Variations of the Temperature of the Atmosphere." They are:—Rio Janeiro, Trevandrum, Madras, Bombay, Frankfort Arsenal, Toronto, Rome, Padua, Kremsmünster, Prague, Muhlhausen, Halle, Göttingen, Salzuflen, Brussels, Plymouth, Greenwich, Leith, Apenrade, Christiania, Drontheim, Helsingfors, Petersburgh, Catharinenburg, Barnaul, Nertschinsk, Matoschkin Schar, the Karian Gate, and Boothia Felix.

It still remained to deduce from single years the monthly means for periods of many years. The temperature tables in the volume of the Transactions of the Berlin Academy for 1847, contain the means for the months, for the seasons, and for the year, as they follow directly from the observations without correction for diurnal variation. These tables have also been calculated in Fahrenheit's scale, and are published in the Report of the Seventeenth Meeting of the British Association, held at Oxford, 1847. Since the publication of this work several stations have been added, and for other stations the means have been determined from longer series of observations.

Lastly, it remained to fill up the wide intervals between the stations by the help of points in the intervening seas. This last work consumed a great quantity of time, as generally speaking the single observations are not even put together in daily means; and besides the mean place of the ship must be determined for each occasion from the continually varying latitude and longitudes. It is only in Beechey's 'Narrative of a Voyage to the Pacific and Behring's Straits,' (which is a true model in point of redaction,) that this has been done. Besides the above work, I have made use of the following, viz. "The United States Exploring Expedition" (in which however, as the distinct Meteorological Appendix has not yet been published, I could only employ the notices found in the text); Captain James Ross's 'Voyage of Discovery and Research in the Southern and Antarctic regions;' and Dumont D'Urville's 'Voyage au Pole Sud et dans l'Oceanie sur l'Astrolabe

et la Zélée'. These three works, with Clerk's 'Daily abstract of meteorological observations made on board the Pagoda,' and King and FitzRoy's 'Narrative of the surveying voyages of the Adventure and Beagle,' describing their examination of the southern shores of South America, have rendered it possible to deduce the isothermals of the Southern Hemisphere much more extensively than could have been done a short time ago, and thus to obtain an approximate determination of the temperature of the southern half of the globe. I have also made use of the following journals:—Vaillant's 'Voyage autour du Monde sur la Bonite;' Du Petit Thouars' 'Voyage autour du Monde sur la Venus;' Duperrey's 'Voyage autour du Monde sur la Coquille;' Freycinet's 'Voyage autour du Monde sur l'Uranie et la Physicienne' (which affords particularly abundant data for the tropical regions); Lütke's 'Voyage autour du Monde sur le Seniavine;' Meyen's 'Reise um die Erde;' Rafaele de Cosa's 'Corsi di osservazioni meteorologiche fatte nella Zona torrida a bordo del Vesuvio;' Hasskarl's 'Meteorologische Waarnemigen op drie Reizen van en naar de Oostindien;' a journal of Dieffenbach during a voyage from England to New Zealand, and one of Schaeyer's on a voyage from England to Australia; Reynolds's 'Voyage of the Potomac during the circumnavigation of the Globe,' and Erman's 'Observations on Board the Krotkoi' in his Russischen Archiv. Lastly, I have used of older voyages, those of Peron and Baudin, La Perouse, Dentrecasteaux, Lisianski, Krusenstern, Chamisso, and the journals of Lawson, Peters and Newbold.

Although, by reason of the smaller variation of the temperature on the surface of the Ocean, observations even of very short period give approximate results, yet the mass of materials which one fancies at first sight one has at command contracts exceedingly in its dimensions on a nearer inspection; for as on land, stations of observation are unnecessarily crowded in some places and altogether wanting in others, so also at sea, there are much-frequented routes, and on the other hand extensive tracts which are hardly ever traversed. The influence of season encounters the inquirer the more frequently in sea observations, because the prevailing winds of different parts of the year determine the most favourable season of navigation for particular routes. Against this inconvenience, we may place the advantage which sea observations possess of getting rid of the often very uncertain correction for the influence of elevation.

From the above materials I have constructed maps both on an equatorial and polar projection of the isothermal curves of January and July; the lines in the January map being for every 4° of Reaumur (every 9° of Fahrenheit), and those in the July map for every 2° of Reaumur (every $4\frac{1}{2}$° of Fahrenheit). It is in these months that the inquiry can be best pursued into the higher latitudes, as in one of them, the southern pole, and in the other, the northern pole, are most nearly approached by navigators. These two months also represent the extreme difference of the distribution of temperature within the annual period, the other months forming intermediate steps between the two extremes. In addition to the isothermal lines, others are drawn which may be termed lines of *normal* temperature: however different the temperature may be at different parts of the same parallel of latitude, yet every parallel of latitude has a determinate mean temperature, which may be found by a graphical interpolation, and which is the proper mean or normal temperature of the parallel at that particular season. Places where the temperature agrees with this value have a normal temperature; those where it is lower are relatively cold, and those where it is higher relatively warm. If we

reckon all places where the winter is too warm and the summer too cool, as belonging to a sea climate;—and all places where the winter is too cold and the summer too hot, as belonging to a continental climate;—the thermic normals will give the boundary lines between these two species of climate. An inspection of the maps of the several months will show whether a place belongs always to one or other of the above classes, or whether it changes its character in this respect in the course of the year.

The greatest winter cold is known to fall in North Asia and North America: on examining the map for January, we see that these two coldest localities form a connected cold region; for the thermic normals by which they are bounded pass, on the Pacific side, along the west coast of America and the east coast of Asia, and unite in Behring's Straits; and on the Atlantic side, when they can be traced no further towards the north, they point exactly to the pole. Now it is in the nature of things that a thermic normal must pass through the pole, for as that point includes in itself all degrees of longitude, it must necessarily correspond to the definition of a point of normal temperature.

The whole of Europe is included in January in the warm space, for the thermic normal coincides almost exactly with the boundary between Europe and Asia; Greenland is also included, but of North America only the narrow strip of coast on the Pacific, beyond the Rocky Mountains. In the tropical region the sea is everywhere warmer in winter, therefore the interior of Africa forms an insulated cool space in opposition to the warm West Indies and the coasts and islands of the Pacific and Indian Oceans. Java and the Sunda Islands have at that season, as compared with the West Indies and Polynesia, a continental climate. We see therefore that these names are unsuitable when comparing places under different latitudes; for it would sound strange to say that Moscow has a sea climate, and that Singapore and Batavia have a continental climate.

In conformity with the shape of the cold spaces, all the January isothermals have their longer axes in a line from America to Asia, passing from the middle of North America beyond the pole to Mandschury.

The terrible January cold of Yakutsk is not corresponded to by any equally cold point in North America. If therefore we assume for this month two poles or maxima of cold, we must assign to them different intensities. But this is not necessary; the course of the curves appears rather to indicate a connected narrow tract from Yakutsk to New Siberia.

But it may be said, how is it possible that if the isothermals for the whole year curve round two separate poles of cold, these poles should not also appear in the several portions of the year? It may be observed in reply, first, that the examination cannot be pursued into the higher latitudes for all the months of the year with equal exactness; but that besides, that may be true on the annual mean which yet has no reality at any single portion of the year. The following example will illustrate this.

A mass of land within the tropics, when the sun is vertical, so increases the heat, that under these circumstances continental stations show temperatures such as are never met with at sea. Now although these continental masses are cooler than the sea in the winter, yet this cooling is less than the disproportionate heating before spoken of, and the mean of the whole year is therefore above the normal. Thus the greater breadth of Africa north of the equator, and the expanse of India, cause the line of maximum mean annual temperature not to coincide with the equator but to run north of that line. We will now suppose the imaginary case of two belts of tropical land at equal distances on each side of the equator, which latter shall

be occupied entirely by sea: we should in such case have two lines of maximum temperature on the mean of the whole year; but not in the separate portions of the year; for the summer heat of the northern zone of land would be simultaneous with the winter of the southern zone, while the temperature of the equatorial sea would always be intermediate between the two.

Hence we see how little one is justified in deriving from the distribution of the mean annual temperature conclusions respecting its distribution in the separate portions of the year: it might even be asserted, on the contrary, that the annual isothermal lines become first elucidated by the consideration of the monthly isothermals; and that for this reason all attempts to refer their form directly to the configuration of the continents have proved unsuccessful.

If we divide the globe at the meridian of Ferro, and compute the temperature of the parallels east and west of that meridian at every ten degrees of latitude, we find (with the exception of the latitudes of 70°) the eastern half, which has the largest mass of land, colder than the western half, the difference diminishing constantly as the equator is approached.

Within the tropics the diminution of temperature in going northward takes place with great regularity. On the eastern side it is represented exactly between 0° and 30° by the equation

$$t_x = 21 \cos 2x,$$

t being in degrees of Reaumur, and x being the latitude; and on the western side it is represented very approximately between 0° and 40° by

$$t = 21.4 \cos (2x - 7).$$

No formula has been found applicable to all latitudes; in latitude 30°–40° the deviation is always considerable. The reason is easily seen; on the American side the Gulf-stream flowing from America to the Azores, and in Asia the lofty mountains and table-lands rising from the lowlands of the Ganges, cause a sudden break in the progression of temperature. As a general formula for the equator and the higher latitudes,

$$t_x = 24.5 + 45.5 \cos^2 x$$

does best; for the lower latitudes,

$$t_x = 24 + 45 \cos^2 x$$

is still nearer. According to this the temperature of the pole is $24\frac{1}{2}$° of Reaumur below the freezing-point.

For the eastern half of the southern hemisphere the formula suits

$$t_x = 5 + 26{\cdot}2 \cos^2 (x - 5).$$

For the polar regions there remains an uncertainty, which however is of less consequence, when the question respects the determination of the mean temperature of an entire hemisphere. We obtain an approximate determination by calculating the mean temperatures of the zones 0 and 10, 10 and 20, and so forth, applying the observational values directly as far as observations suffice, and employing for the highest latitudes the value given by interpolation. Admitting these determinations to be only a first approximation, they still appear less uncertain than the wholly arbitrary method hitherto employed, of proceeding along a given meridian and deducing therefrom the mean temperature of the pole; the values may be improved subsequently by combining the temperatures of the eastern and western hemispheres into a whole by means of Bessel's formula, and the form of the function being left indeterminate, by the addition of members the observational values will be reproduced as nearly as possible.

As provisional values, I find—

		Reaumur.	Fahrenheit.
January.	Northern Hemisphere........	7°·5	48°·8
	Southern....................	12·2	59.5
	The Globe..........	9·9	54·15
July.	Northern Hemisphere........	17·3	71·0
	Southern....................	9·6	53·6
	The Globe..........	13·5	62·3

The temperature of the whole globe increases therefore fully 3½ degrees of Reaumur, or 8 degrees of Fahrenheit, from January to July. If we take the mean between these months, we have as the mean temperature of the globe, 11°·7 Reaumur, or 58°·2 Fahrenheit; as the mean temperature of the northern hemisphere 12°·4 Reaumur, or 60° Fahrenheit; and of the southern hemisphere 10°·9 Reaumur, or 56°·4 Fahrenheit. As when we move southwards we see the northern constellations sink and the southern rise above the horizon, so the sun on entering new signs in his annual course, overlooks constantly new portions of the earth's surface. This surface being a highly varied one, the sun's influence on it is also constantly varying, for the impinging solar heat is employed in raising the temperature of substances which do not change their condition of aggregation; but when engaged in causing the melting of ice or the evaporation of water, it becomes latent. When therefore the sun returning from its northern declination enters the southern signs, the increasing proportion of liquid surface upon which it shines causes a corresponding part of its heat to become latent; and hence arises the great periodical variation in the temperature of the whole globe, which has been noticed above.

These relations appear to contain within themselves an important motive force in the machinery of the whole atmosphere, for they are conditions on which a periodical transition of aqueous vapour into a liquid state depends. The circulation of moisture, which acts so importantly on all vegetable and animal life, thus appears no longer dependent on merely local effects of cooling, or the intermixture of currents of air of unequal temperature; the non-symmetrical distribution of land and sea in the two hemispheres necessarily causes the aqueous vapour, which is developed in a preponderating degree over the southern hemisphere from the autumnal to the vernal equinox, to return to the earth in the form of rain or snow during the other half of the year. Thus the wonderful march of the most powerful steam-engine with which we are acquainted, the atmosphere, appears permanently regulated by laws of periodical action.

Men often complain that all physical circumstances are irregularly distributed over the earth's surface; but this very irregularity is, as we have just seen, a preserving principle of the whole terrestrial life.

It is probable that the northern hemisphere acts as the condenser, and the southern hemisphere as the water reservoir of this steam-engine; and thus that a greater quantity of rain falling in the northern hemisphere is one cause of its higher temperature, since the heat which became latent in the southern hemisphere is set free in the northern in heavy falls of rain.

But if all these phænomena are essentially connected with the proportion

and distribution of land and sea, they must have been different when these proportions and distribution were different. Generally speaking, the rising up of new masses of land must have condensed a certain quantity of the existing aqueous vapour, from the proportion of latent heat having been changed; but the place where the solid mass was elevated must be of the greatest importance in this respect. Thus considerable atmospheric convulsions would have been among the secondary consequences of sudden geological revolutions, until the movements of the atmosphere had become accommodated to the new circumstances of the surface on which it rests. Speaking generally, the temperature of the entire surface of the globe must have augmented with every augmentation of the solid portion of its area.

If we now return to the consideration of the annual periodical variation of temperature over the whole surface of the globe, it may appear surprising to find that it is greater than that of the southern hemisphere taken separately; the variation of the whole globe being $3\frac{1}{2}°$ Reaumur, or 8° Fahrenheit; and that of the southern hemisphere only 2°·6 Reaumur, or 5°·9 Fahrenheit; whilst the variation of the northern hemisphere is 9°·8 Reaumur, or 22°·2 Fahrenheit. It is only the two latter values however which can be properly compared with each other; for the difference between the periodical variation of the northern and the southern hemispheres expresses the difference of effect produced by the variation of the sun's meridian altitude in his annual course, according as land or sea predominate in the surface which receives his rays: the annual variation of the temperature of either hemisphere taken separately, being due to the variation in solar action, the receiving surface remaining the same. The annual variation of temperature of the whole earth, on the contrary, arises from the periodical variation in the surface brought under the sun's rays, with no inequality in the conditions under which those rays are dispensed.

We will now consider more closely the manner in which the position and form of the isothermals alter from January to July.

The concavities of the *January* isothermals fall,—in America in the middle of the continent,—in the Old World, although still in the interior, yet much nearer to the eastern than to the western coast: the convex summits are in the intervening oceans. The isothermal curves rise steeply from Labrador to Spitzbergen, and descend almost perpendicularly to the European coast; from Norway to Nova Zembla, their eastern sides even form overhanging summits. The influence of the Gulf-stream is unmistakeable. The line of 0° Reaumur, or 32° Fahrenheit, passes from Philadelphia across the banks of Newfoundland, and through the southernmost part of Iceland up to the Polar circle, which it reaches in the meridian of Brussels. It thence descends quite perpendicularly, or in the direction of the meridian, to Holland, from whence it proceeds in a south-easterly direction to the Balkan: from the middle of the Black Sea it runs in a west and east course across Asia to the Corea, whence it rises to the Aleutian Islands and descends again in America to the latitude of Palermo. Thus we find that if we proceed in January from the Shetland Islands down the east coast of Great Britain to the channel, we do not alter the temperature, whilst with every step to the westward it becomes warmer, and that in no inconsiderable degree; since both the west coast of Ireland and the extreme point of Cornwall are beyond the line of 4° Reaumur, or 41° Fahrenheit. In Scandinavia the circumstances are still more extraordinary: from the intervention of the British Islands, the southern parts of Norway are less open to the warm sea current than the northern parts, and hence in the month of January the temperature actually becomes

warmer in proceeding from south to north, and at the north cape the south-east winds are the coldest. Both the Scandinavian Alps and the Rocky Mountains in America form dividing walls in respect to climate.

In approaching the tropics the curves flatten; the isothermal of 16° Reaumur, or 68° Fahrenheit, nearly coincides throughout its course with the tropic of Cancer, its concavities in Africa and Trans-Gangetic India, and its intervening convexity in Hindostan, being quite inconsiderable.

The dividing isothermal between the northern and southern thermal hemispheres, 21° Reaumur, or 79°·2 Fahrenheit, is only a simple line in the neighbourhood of the Gallapagos, but branches out beyond on either side so as to enclose a connected space of highest temperature, narrow in the Atlantic, but spreading out in width in South Amrica, the Indian Ocean, and Equatorial Polynesia beyond Australia. Out of this space it is only exceptionally (as for example on the north coast of Australia) that we find temperatures of 22° Reaumur or 81½° Fahrenheit, but not forming any continuous line. The fact of the space of highest temperature advancing farthest into the southern hemisphere in the Indian Ocean, and of this being also the locality of highest absolute temperature, are the reasons of the north-east trade becoming at this season a north-west monsoon.

In the month of January the greatest difference of mean temperature comprised between 70° north and 70° south latitude, is 54° Reaumur, or 121°·5 Fahrenheit. The thermic equator falls everywhere, excepting in Columbia and in Guinea, in the southern hemisphere; but between this line and the latitude of 70° south, there are only twenty-two isothermals, while between it and 70° north there are fifty-four such lines.

The isothermals of the southern hemisphere have the peculiarity of being much more inflected in the torrid than in the temperate zone. Where the alternation of land and sea from east to west ceases, the causes of inflection are absent. Besides the different effect of radiation on a solid or a liquid base, the configuration of continents is also influential in other ways. On it depend the courses of marine currents, whose influence becomes clearly apparent in the prosecution of such an examination as the present. In drawing the isothermal lines across the Ocean, they depend exclusively on the observations of atmospheric temperature, the numerous observations of the temperature of the sea never being taken into account. This distinction is imperative where the atmospheric isothermals are the objects of representation, and where we aim expressly at obtaining as accurate a distinction between cause and effect as possible.

The cooling influence of the polar current on the coast of Chili was discovered by M. de Humboldt; its amount is not the same throughout the year, but it is unmistakeably sensible at all seasons. This causes the convex summits of the isothermals (which in the southern hemisphere mark the coldest localities) to be always on the western coast of America, and the concavities on the eastern coast. The reason of this persistency is to be found in the cold current in question not being a superficial one, but having, as it appears from soundings taken in the voyage of circumnavigation of the Venus, a depth of 5480 feet. "C'est une section considérable des mers polaires marchant majestueusement du Sud au Nord."

The great curvature of the isothermals in the Southern Atlantic, is shown by a comparison of the temperatures of Rio Janeiro, St. Helena, Ascension, Christiansburg, Cape Town, and the Isle of Bourbon. The character of the vegetation at St. Helena must for this reason differ materially from that of the New Hebrides. Even if we assume a greater decrease of temperature

with increasing elevation than is shown by the observations at St. Helena, we shall still find the temperature there much lower than that of the Archipelago of the Low Islands. The reason of this great inflection of the isothermal lines having been hitherto overlooked, is probably that navigators usually keep nearer either the American or the African coast, and that thus the southern tropic is rarely crossed in the Atlantic in mid-ocean.

To the south of the Cape of Good Hope, the isothermals flatten and are much-crowded: this crowding is still more striking in March, when the isothermals of the torrid zone have their concavities, and those of the temperate and frigid zones their convexities, in the meridian of the Cape.

It has only been possible to determine directly the position of the line of 0° Reaumur, or 32° Fahrenheit, in the southern hemisphere, for the four months of December, January, February, and March. It is comparatively but little inflected; these determinations however can only be regarded as approximate, if we consider that the drift-ice of the Antarctic regions, being everywhere exposed to the uninterrupted action of an open ocean, although it may consist of more compact masses, yet can never form into such extensive fields as the ice of the northern seas, and from its state of disruption is far more variable in its place in different years. The boldness with which Captain Ross broke through the zone of moveable ice which he met with in the place where Dumont D'Urville had found an open sea, was recompensed by finding beyond it a sea free from ice, which permitted him to advance to far higher latitudes; from a comparison of the different voyages, we arrive however at a conviction, that before reaching the barrier of fixed ice the temperature dependent on the position of the moveable ice may vary very considerably in different years. If we were enabled to sketch the isothermals of a year, we might perhaps find an increase of temperature beyond the moveable belt of drift-ice. By the combination of the results of different single years, there may appear a local curvature which in the mean of many years would soften off into simpler forms. We may explain in this manner the apparently contradictory statements of different circumnavigators on the temperature of the southern hemisphere. From not being acquainted with the part to be attributed to non-periodic variations, the observed atmospheric relations on each occasion have been regarded as the normal ones. It was overlooked that a traveller visiting Berlin in January 1823, would have found there the mean January temperature of Godthaab (in Greenland), of Bear Island, and of Moscow; and in January 1834, a temperature higher than the mean January temperature of the plains of Lombardy.

In *February* the isothermals in Northern Asia begin to move northwards, while in North America they are still moving southwards. In Baffin's and Hudson's Bay they become still steeper than before, while in Siberia they begin to flatten. Near the thermal limits between the northern and southern hemispheres, the temperature of 22° Reaumur, or 81½° Fahrenheit, is found in two separate spaces, one in the interior of South America, the other in Central Africa, where it extends to Australia, the larger part being in the southern hemisphere, but in Guinea extending to 10° north of the equator. In the southern hemisphere the distribution has altered but little; in Australia the east and west sides continue to be cooler than the middle until after the beginning of March.

In *March* the spaces in America and Africa, enclosed by the isothermal of 22°, or 81½° Fahrenheit, have united; the inflection in the middle of the Atlantic still recalls their separation in February. The flattening of the Asiatic curves has become still more decided, and shows itself unmistakeably in the

European curves, with the exception of the Scandinavian curves, which maintain their deviating form. It is only in the Kirghis steppe that the depression of temperature still continues to be remarkable, and does not disappear until April. The American curves become flatter in the interior of the continent, but as they preserve their steepness on the eastern coast, their concavity moves gradually towards Newfoundland. The Atlantic ocean shows the peculiarity that the curves on this side of the tropic of Cancer have their convex summits in the same meridian (that of the Cape de Verd Islands) in which the inter-tropical curves have their concave summits. This is explained by the Gulf-stream turning to the south at the bank of Flores. On the western coasts of North and South America the form of the curves remains the same, the convex summits are everywhere close to the coast. In the Ethiopian Sea the curves are flatter, and are very close together near the Cape of Good Hope and on the south coast of Australia, because the line of 0° Reaumur, or 32° Fahrenheit, has its convex summit in these meridians in 57° lat., and the increase of temperature from thence, which is at first slow, becomes extremely rapid from 45° S. lat.

In *April* two spaces of unusually high temperature, bounded by isothermals of 24° Reaumur, or 86° Fahrenheit, are developed in the middle of Northern Africa and in the interior of Western India. Everywhere in Asia and middle Europe, the isothermals are almost parallel with the parallels of latitude. It is only the curves of 4°, 0° and —4° Reaumur, 41°, 32° and 23° Fahrenheit, which preserve their extraordinary bend. The line of —4° Reaumur, or 23° Fahrenheit, passes from the southern part of Hudson's Bay along the west coast of Greenland up to Spitzbergen, and sinks from thence down to the entrance of the White Sea. The line of 0° Reaumur, or 32° Fahrenheit, runs from Cape Breton to the south point of Greenland, through Iceland, almost up to Bear Island; thence to the North Cape, and sinks on the crest of the Scandinavian Alps down to the latitude of Drontheim, from whence it bends eastward. The ice drifting down from the coast of Greenland and Baffin's Bay is the cause of this phænomenon.

In *May* this effect of the drift-ice is still more decided; from Nova Scotia to Newfoundland the isothermals are crowded most closely together: hence arises in the spring of Newfoundland the remarkable phænomenon of the silver dew, when warm south winds cover the trees with a thick crust of ice, converting, as Bonnycastle tells us, every tree into a candelabra of the purest crystal; hence too the thick fogs which at this season obscure the entrance to Baffin's Bay. Meanwhile the hot space in Africa, bounded by an isothermal of 24° Reaumur, or 86° Fahrenheit, has extended and united itself with the hot space in Western India. On the northern side of this space the temperature decreases rapidly up to the shores of the Mediterranean: the S.E. trade in the form of a S.W. monsoon, advances towards the hot space. The curves in Northern Asia, which in the interior continue parallel to the circles of latitude, on approaching the east coast of the old continent, rise rapidly, and then sink down again with equal rapidity in Kamschatka, towards the Aleutian and Kurile Islands.

In *June* the relations are analogous; the hot African space reacts in Europe up to Christiania; for the European isothermals still rise near the west coasts, and do not begin their easterly course until the meridian of Berlin. The Fox Channel, the Karian Gate, and Behring's Straits, as outlets of the Icy Sea, show their influence in producing concave inflections in the generally regular course of the isothermal lines at this season. In America, the lowest parts of the lines are close to the east coast; the warm space, enclosed by a

line of 22° Reaumur, or 81½° Fahrenheit, which had been formed in the Caribbean Sea in May, now embraces the whole of that sea and the entire Gulf of Mexico. In the southern hemisphere the curves have become extremely flat; and even the difference between the east and west sides of South America is less sensible. The cooling effect produced by the melted drift-ice has undergone a considerable diminution.

In *July* the extreme temperatures manifest themselves; within the elongated space enclosed by the isothermal of 24° Reaumur, a space enclosed by an isothermal of 26° Reaumur, or 90½° Fahrenheit, has been formed, including Nubia and Southern Arabia. These are the countries of which Hagi Ismael says the earth is fire and the wind flame. But in Western India also the temperatures have become since May extraordinarily high. The Afghans say, "Great God, why needest thou have made Hell when there is Ghizni?" It is no wonder therefore that the S.E. trade in the form of a S.W. monsoon follows up the retreating N.E. trade to the foot of the Himalaya. In Europe and Asia the isothermals have overpassed the circular form (*i. e.* coincidence with the parallels of latitude), and begin to be convex in the interior of the continent. The thermic normal, enclosing a space warmer than the normal condition, includes all Asia, Europe, and Africa down to the equator; only Scotland and Ireland belong to the proper sea climate, as do also Labrador, Canada, New North and South Wales, and the margin of coast from California up to the mouth of the Mackenzie River. In the warm space of the Mexican Gulf, we find no traces of temperature so high as those of Africa and Hindostan; Maracaybo only reaches 24° Reaumur, or 86° Fahrenheit. The thermal limit between the northern and southern hemispheres is a little advanced towards the north in this part of the globe, but on the eastern side it touches the northern tropic in several places.

The longitudinal axis of the isothermals runs westward from the Aleutian Islands towards Baffin's Bay, but the issues of the Icy Sea, the Karian Gate, and Barrow's and Behring's Straits, draw out the circular form of the isothermal surrounding the pole into a more nearly triangular shape. As in North America the isothermals have moved laterally, their concavities having advanced from the interior to the east coast, while in Europe and Asia the concave form has been changed into a convex one, their July course in the greater part of North America, in Europe, and in Asia is perpendicular to the direction which they follow in January. In the southern hemisphere, the isothermals, from 12° to 1° Reaumur, or from 59° to 34°·2 Fahrenheit, are thickly crowded and extremely flat.

In *August*, in the old continent the east side of Nova Zembla alone resists the still continuing tendency of the curves to become more convex, and hence they assume two characteristic convexities, one at Spitzbergen, and the other beyond the mouth of the Lena. But on the coast of Greenland, as the cold in the high north already begins to increase, the drifting of ice to the southward is lessened, and the east coasts of North America are thus permitted to retain more of the heat they receive, and the isothermal curves become flatter.

In *September* this is the case in a still greater degree; and as the cold from New Siberia now begins to invade the continent of Asia, the convex summits are similarly flattened. This therefore is the season when the distribution of temperature over the globe is most regular, even America forming no exception. Now begins the Indian summer, "the time which the Great Spirit of the Red-skin sends to him that he may follow the chase." The same

causes render September, as has been shown in the memoirs on the "Non-periodic Variations," the month which shows the fewest anomalies in single years; for when the temperature is equally distributed in the east and west direction, easterly and westerly winds or currents of air cease to exert any disturbing thermal effect. Hence we prefer September as a travelling month, and our after-summer, though less beautiful than that of America, is not without charms. Nature falls gently asleep in autumn, and awakens with feverish starts in spring; if the last-named season were not set off by winter as a foil, autumn would surely stand the higher in our estimation.

Within the tropics the temperature begins already to sink, showing clearly that as the sun passes from the northern to the southern signs, a larger portion of the heat dispensed by his rays becomes latent. The West India Islands are now withdrawn from the space enclosed by an isothermal of 22° Reaumur, or 81½° Fahrenheit, which has now contracted to a narrow strip of coast from Vera Cruz to Cayenne; the space included by the same isothermal in Africa has retreated from the west coast to the interior; and the space enclosed by an isothermal of 24° Reaumur, or 86° Fahrenheit, now only includes Kordofan, Nubia, and Arabia, and no longer embraces Hindostan.

In *October* it begins to disappear. The cold now comes in decidedly from the north; at the mouth of the Yana the isothermal of — 22° Reaumur, or — 17½° Fahrenheit, already touches the continent of Asia, and the temperature of Melville Island has sunk to — 16° Reaumur, or — 4°·8 Fahrenheit. The cold comes in the old continent from the north-east, and in the new continent from the north-west. But it is not until *November* that the isothermals become in both continents decidedly concave. At the same time the curves in the southern hemisphere become increasingly inflected as the increasing altitude of the sun, causing the ice to melt, renders the difference between land and sea more marked.

The isothermals of the torrid zone north of the equator, on the contrary, run almost completely in the direction of the parallels of latitude. In Europe meanwhile those extraordinary involutions have already begun which in *December* are still more decidedly formed, and which cause the isothermal of 4° Reaumur, or 41° Fahrenheit, to run from the Feroe Islands to Rochelle, passing along the west coast of Great Britain. In a similar manner the south point of Nova Zembla and the Kirghis Steppe have now the same temperature. In the curves of December we recognise already almost the extreme forms of January.

Such important variations in the distribution of temperature cannot but react in the strongest manner on the movements of the atmosphere, and consequently also on the distribution of the atmospheric pressure. Graphical representations of a fresh and more detailed examination of the annual variations of the pressures of the gaseous and aqueous atmospheres which are now lying before me, show that the interchange between masses of air does not only take place between the northern and southern hemispheres, but that a *lateral flowing off* also takes place at certain times. Thus in the spring of the year the air accumulates over the part of America where the cold still continues; while in Asia the increasing warmth already causes it to expand so that its amount and pressure are diminished. Hence the countries which have a *cold spring* (as the Arctic regions of North America), have the maximum pressure in the spring, as the author showed fifteen years ago (Pogg. Ann. xxiv. p. 205); hence the west coasts of America have the maximum of pressure in summer; and the interior of Asia, on the contrary, has its minimum of pressure in summer, as the longitudinal axis of the isother-

mal lines falls in summer in the ocean, and in winter on the continents. In the same manner the occurrence of two isolated closed spaces in Hindostan converts the trade into a monsoon, while in summer northerly breezes (the Etesian winds), which have their point of attraction in Africa, blow over the Mediterranean. Hence the sub-tropical zone is wanting in Asia, while the smallness of the alteration in the position of the isothermal lines, 12° to 20° Reaumur, or 59° to 77° Fahrenheit, in the Atlantic, fixes it to a definite place. Hence also the distribution of temperature in the thermic wind-rose is of an opposite kind according as the place is situated on the eastern or the western side of a continent.

In conclusion, the results here communicated will, I trust, appear to justify the expression of a wish, that when meteorological observations are published, their value may not be lessened, as has so often been the case heretofore, by publishing only the means of the seasons and of the year; but that the monthly means will be also published.

On the Progress of the Investigation on the Influence of Carbonic Acid on the Growth of Ferns. By Dr. Daubeny.

Dr. Daubeny reported that the ferns were now growing in a large excess of carbonic acid, the amount of which had been ascertained daily during the last month. He however suggested some modifications in the form of the apparatus, the object being to secure the gas from leakage more perfectly than had hitherto been done.

Notice of further Progress in Anemometrical Researches. By John Phillips, F.R.S.

Referring to the report on this subject, presented to the Southampton Meeting of the Association and printed in the Transactions, the author recapitulated the steps of the investigation by which he had been conducted to propose the evaporation of water as a measure of the velocity of air-movement. In the former researches, the conclusion which may be drawn *à priori* from Dr. Apjohn's formula for the relation of the temperature of the dew-point to that of an evaporating surface, was verified; and the *rate of cooling* of a wet bulb in the open air was found to be, *cæteris paribus*, simply proportional to $t-t'$ (t being the temperature of the air, t' that of an evaporating surface). The air-movement was found to affect the rate of cooling, nearly in proportion to the square root of the velocity; and thus by simply observing the rate of cooling of a wet bulb exposed to a current of air, and also the value of $t-t'$, the velocity of the air current becomes easily calculable. But this instrument is only an *Anemoscope*, of extreme delicacy and various applicability indeed, but incapable of being converted to a self-registering *Anemometer*.

It appeared to the author probable that the *rate of evaporation* followed nearly or exactly the same law as the rate of cooling, the same reasoning in fact applying to each case. This was tested by experiment in a great variety of ways, with instruments of extremely various forms, and with velocities of air-movement from 400 yards to 27,000 yards in the hour. The velocities of the wind were measured by a very lightly-poised machine anemometer of Dr. Robinson's construction, but without any wheel-work, the revolutions being counted by the observer.

In the course of these experiments some apparently anomalous circumstances in the rate of evaporation occurred to the author, but these he hopes to be able to interpret by further careful research, and finally to present in the compass of a few cubic inches an anemometer specially suited to measure and record the low velocities of wind, and furnish a useful complement to the larger machines already esteemed to be so important in meteorology.

To the Assistant-General Secretary.

Dublin, 27th of July, 1848.

Dear Sir,—For the last four months I have been so much out of health by previous over-exertion of mind and body, that some repose became indispensable, and I regret to say that I shall be unable, from this cause, to complete the Report on the Facts of Earthquakes, entrusted to me by the British Association, so as to present it, as I had hoped and intended, at the ensuing Meeting. Much progress has been made with the most laborious parts of it, and should health permit, I expect to have the honour of presenting it next year, in case the Association deem me worthy of continuing the recommendation for the Report.

It is also my duty, as the first named on a Committee for the Construction of a Self-Registering Seismometer, to state the progress that has been made:—

Working drawings of the instrument and of its several parts have been prepared and carefully considered, but as the acting members of the Committee were unwilling to incur any outlay for actual construction, until perfectly clear in every respect as to the principles and details of the instrument, and as some questions arose of considerable mathematical nicety in determining, they have not as yet put into hand any part of the work. Professor Lloyd, one of the Committee, has kindly promised the reporter to solve those questions, when we expect that the instrument will be forthwith completed, and a plan determined for its being set to work. We have therefore to ask the Association to continue to the same Committee and in the same form the grant of 50*l.* made last year for the above purposes. Robert Mallet.

Concluding Report on the Gaussian Constants. By Adolphe Erman.

The annexed addition to this year's Report on the Correction of Gaussian constants consists in tables containing primary equations for the 24 unknown, viz. the corrections of the constants, resulting from magnetic elements observed in the Atlantic Ocean, and in some points of the North Sea and of the Baltic, and a final table (marked (14), and to be substituted for Table (6) of the first report printed in the volume for 1846), presenting again *the* 24 *final equations for the* 24 *corrections* in the last and most complete form that may be given to these expressions by the whole set of observations that has till now come to our disposal. Indeed these equations are the full abstract of what can be added to the Gaussian theory of terrestrial magnetism, by 610 magnetic elements between April 1828 and November 1830; and as each of the primary equations relating to points between Taheiti and Portsmouth reposes upon a due combination of from three to five single observations, the number of contributing observations amounts to upwards of 900. A simple resolution of these equations will now assign to the corrections $\Delta g^{4,0}$, $\Delta g^{4,1}$..... (that must be applied to $g^{4,0}=-108{\cdot}855$, $g^{4,1}=-152{\cdot}589$..... viz. to the numbers previously adopted by M. Gauss), the most probable values that can be obtained by the before-said stock of data for 1829, and the weight of the same corrections.

A. Erman.

Stations and observed elements		Latitude.	Long. East, Greenwich.	Log. n.	Log. coef. $\Delta g^{4.0}$.	Log. coef. $\Delta g^{4.1}$.	Log. coef. $\Delta h^{4.1}$.	Log. coef. $\Delta g^{4.2}$.	Log. coef. $\Delta h^{4.2}$.	Log. coef. $\Delta g^{4.3}$.	Log. coef. $\Delta h^{4.3}$.	Log. coef. $\Delta g^{4.4}$.	Log. coef. $\Delta h^{4.4}$.	Log. coef. $\Delta g^{3.0}$.	Log. coef. $\Delta g^{3.1}$.	Log. coef. $\Delta h^{3.1}$.	Log. coef. $\Delta g^{3.2}$.	Log. coef. $\Delta h^{3.2}$.	Log. coef. $\Delta g^{3.3}$.	Log. coef. $\Delta h^{3.3}$.	Log. coef. $\Delta g^{2.0}$.	Log. coef. $\Delta g^{2.1}$.	Log. coef. $\Delta h^{2.1}$.	Log. coef. $\Delta g^{2.2}$.	Log. coef. $\Delta h^{2.2}$.	Log. coef. $\Delta g^{1.0}$.	Log. coef. $\Delta g^{1.1}$.	Log. coef. $\Delta h^{1.1}$.
Tobolsk, upper part of the town	δ.	58 11 40	68 16 5	1.36727	8.82338	9.38498	8.77699n	9.64497	9.61926	9.37000n	9.82317	9.76597n	8.50219	9.01911	9.68352	9.27526n	9.82459	9.77189	9.42389n	9.89650	9.05450	9.88210	9.56156n	9.90393	9.83309	8.82413	9.94529	9.66950n
Item, lower part	δ.	58 12 15	68 16 42	1.39007	8.82366	9.38525	8.77723n	9.64484	9.61941	9.37040n	9.82290	9.76564n	8.44613	9.01926	9.68368	9.27529n	9.82442	9.77197	9.42433n	9.89616	9.05458	9.88218	9.50151n	9.90370	9.83314	8.82416	9.94533	9.66940n
Dengikowo	δ.	59 57 48	69 55 43	1.42363	8.87853	9.42903	8.82511n	9.62319	9.63625	9.41702n	9.77332	9.69882n	8.41017n	9.04980	9.70701	9.28367n	9.79134	9.77932	9.46714n	9.83903	9.07115	9.80338	9.55393n	9.86313	9.83306	8.83273	9.94947	9.65373n
Jelsarowo	δ.	61 15 0	68 21 34	1.50944	8.89001	9.45207	8.94039n	9.64510	9.60566	9.29383n	9.75860	9.64678n	8.41945	9.04550	9.71522	9.34128n	9.80261	9.74040	9.33620n	9.81804	9.05745	9.89243	9.58875n	9.86719	9.78932	8.81355	9.94310	9.67731n
Shorkal	δ.	62 44 20	65 34 8	1.47266	8.88369	9.47228	9.06973n	9.67510	9.54660	9.01316n	9.73899	9.57004n	8.97874	9.02264	9.71992	9.41490n	9.82068	9.67188	9.04057n	9.79143	9.02444	9.88771	9.63660n	9.87718	9.71423	8.77454	9.93195	9.71199n
Ajewski Wolok	δ.	56 34 50	71 49.4	1.23651	8.80772	9.34962	8.47620n	9.58284	9.67143	9.57965n	9.81578	9.81572n	9.10575n	9.02906	9.67358	9.15303n	9.78056	9.83746	9.64637n	9.89886	9.07843	9.88665	9.48015n	9.87156	9.90772	8.85588	9.95697	9.61555n
Ojasch	δ.	55 37 15	84 0.4	0.89600	8.77967	9.32265	8.34322	9.17839	9.76666	9.85918n	9.48935	9.55588n	9.79355n	9.01796	9.67789	8.52367n	9.42436	9.94870	9.94012n	9.58979	9.07622	9.90807	9.11906n	9.54307	0.02973	8.85856	9.98916	9.31913n
Kasulka	δ.	56 1 30	91 46.4	0.95235	8.71551	9.32720	8.62862	8.15196n	9.78224	9.88906n	8.09400n	8.37251	9.84281n	8.94650	9.63505	8.43574	7.85221	9.96550	9.97093n	9.13246n	9.00096	9.91060	8.17790n	8.49547	0.04736	8.78123	9.99845	8.76984n
Alsalewsk	δ.	55 27 6	98 36.4	0.53359	8.56085	9.29836	8.75936	9.21570n	9.76571	9.86446n	9.48628n	9.57125	9.79686n	8.80233	9.67208	8.91294	9.30532n	9.95577	9.95087n	9.56013n	8.86220	9.91172	8.97959	9.42337n	0.04208	8.64543	9.99797	8.93310
On the ice of Lake Baikal	δ.	52 3 48	106 11 46	0.94727n	8.09408	9.15396	8.74804	9.49515n	9.69803	9.78188n	9.81823n	9.91912	9.62085n	8.41097	9.60491	9.10044	9.70272n	9.91795	9.88750n	9.91925n	8.50644	9.88737	9.32656	9.80018n	0.02703	8.30850	9.98545	9.44433
Mansursk	δ.	53 25 0	105 41.4	0.95919n	8.20067	9.21202	8.78901	9.48673n	9.71029	9.77679n	9.78632n	9.86916	9.61331n	8.48426	9.62909	9.10645	9.68106n	9.91785	9.87465n	9.87927n	8.56473	9.88959	9.31150	9.77003n	0.01536	8.35899	9.98589	9.38127
Ustkuzk	δ.	56 46 3	105 57.4	0.58311n	8.36202	9.33001	8.88817	9.49553n	9.71870	9.71897n	9.73365n	9.76267	9.49553n	8.58022	9.68017	9.14916	9.66321n	9.89883	9.79911n	9.80896n	8.62790	9.96765	9.32619	9.73462n	9.97858	8.40443	9.98726	9.37544
Iwanowsk	δ.	58 37 44	110 34.4	0.83116n	8.22245	9.37512	8.98956	9.59635n	9.66752	9.53530n	9.78055n	9.74571	8.95697n	8.41186	9.69450	9.26980	9.75595n	9.83365	9.60651n	9.84841n	8.44369	9.00525	9.43711	9.82207n	9.90113	8.21130	9.97530	9.51356
Nelensk	δ.	60 0 0	118 28.4	1.24125n	7.55601	9.38744	9.12686	9.70564n	9.52219	8.74103n	9.81103n	9.66103	9.30091	7.72682	9.68448	9.41824	9.85954n	9.67735	8.80638n	9.83348n	7.74790	9.08242	9.01279	9.92175n	9.71645	7.50934	9.94533	9.67379
Issik	δ.	60 47 6	125 58.4	1.30300n	7.52345n	9.37295	9.23131	9.75964n	9.26819	9.28928	9.77280n	9.43485	9.57655	7.68444n	9.65743	9.51999	9.90911n	9.41587	9.34906	9.83180n	7.60968n	9.83791	9.71296	9.96833n	9.47387	7.45774n	9.90648	9.77200
Antzelm	δ.	61 0 59	138 39 50	1.35874n	6.91512	9.28846	9.34492	9.77689n	8.83347n	9.70790	9.53807n	9.58866n	9.64386	7.06336	9.57218	9.62769	9.92475n	9.03038n	9.76597	9.59626n	7.07696	9.76216	9.81111	9.98290n	9.85168n	6.83402	9.82047	9.87508
Ketanda	δ.	60 40 12	141 17 24	1.39107n	7.54776	9.25477	9.35459	9.77127n	9.11306n	9.74978	9.44578n	9.29500n	9.63001	7.71018	9.54481	9.64023	9.92139n	9.26057n	9.80944	9.50588n	7.72629	9.73859	9.83139	9.98105n	9.31844n	7.48483	9.79909	9.80038
Sea of Ochozk	δ.	58 14 39	150 29 30	1.10825n	8.22031	9.06398	9.34627	9.72236n	9.48096n	9.84905	6.93469	9.70509n	9.45895	8.41531	9.40952	9.65836	9.89038n	8.64730n	9.91949	9.96096n	8.45029	9.63437	9.86494	9.96212n	9.71385n	8.21969	9.71234	9.93782
Item	δ.	58 14 39	150 42 2	1.01905n	8.23457	9.05994	9.34733	9.72050n	9.49200n	9.84902	7.94666	9.70850	9.44830	8.42957	9.40664	9.65923	9.88872n	9.65273n	9.91950	8.87304	8.46455	9.63701	9.86571	9.96053n	9.71872n	8.23395	9.71034	9.93352
Item	δ.	58 15 26	151 53 29	0.77781	8.31169	9.03636	9.35361	9.71015n	9.51918n	9.84768	8.69460	9.72490n	9.38005	8.50648	9.38993	9.66427	9.87880n	9.67878n	9.91823	8.73817	8.54136	9.61875	9.87002	9.95096n	9.74485n	8.31169	9.67892	9.93742
Item	δ.	58 14 45	151 54 34	0.87670	8.31209	9.03570	9.35345	9.70998n	9.51962n	9.84787	8.70043	9.72510n	9.37930	8.50706	9.38950	9.66431	9.87872n	9.67929n	9.91848	8.77434	8.54203	9.61847	9.87006	9.95094n	9.74540n	8.31142	9.69872	9.93750
Item	δ.	58 16 43	151 57 40	0.68033	8.31734	9.03566	9.35465	9.70954n	9.52067n	9.84717	8.71402	9.72488n	9.37497	8.51181	9.38928	9.66486	9.87807n	9.68007n	9.91771	8.77842	8.54645	9.61813	9.87038	9.95015n	9.74601n	8.31571	9.69832	9.93764
Tiguiisk	δ.	57 45 55	158 36 24	0.57566n	8.59938	8.83251	9.36781	9.63183n	9.63692n	9.82329	9.44734	9.78201n	7.87418n	8.80160	9.26538	9.68108	9.80997n	9.79823n	9.89774	9.50617	8.84[illegible]	9.52949	9.88851	9.88838n	9.86541n	8.61227	9.62054	9.95[illegible]
Klutshewsk	δ.	56 19 55	160 42 17	1.18473	8.61806	8.66581	9.33406	9.59520n	9.66545n	9.82752	9.56490	9.87870n	9.01591n	8.84374	9.18761	9.66851	9.78766n	9.83690n	9.91001	9.63650	8.89538	9.18428	9.88751	9.87536n	9.91088n	8.67409	9.59785	9.96023
Pacific	δ.	48 15 0	171 9.4	1.45864	8.55138	8.71352n	9.01600	9.20913n	9.71688n	9.70500	9.92696	9.89071n	9.94553n	8.99857	6.60766n	9.55317	9.55430n	9.96300n	9.85280	0.04783	9.14307	9.11133	9.86184	9.72678n	0.08126n	8.96927	9.40725	9.98334
Item	δ.	47 4 0	176 36.4	1.54878	8.57786	8.91209n	8.91605	8.69839n	9.72016n	9.43061	9.98709	9.75307n	0.06862n	9.08315	8.75407n	9.52465	9.27557n	9.98509n	9.62237	0.11948	9.24557	8.74315	9.85011	9.52278n	0.11751n	9.07994	9.17240	9.98896
Item	δ.	47 58 0	186 47.4	1.13462n	8.78109	9.10893n	8.86892	9.12706	9.71051n	9.32611n	9.97954	9.32560	0.05518n	9.24114	9.14432n	9.51406	9.08339	9.98334n	9.34774n	0.11648	9.38973	8.77662n	9.85599	8.82120	0.12027n	9.21785	8.82821	9.99298
Item	δ.	49 54 0	197 34.4	1.43668	8.99045	9.23803n	8.80841	9.27704	9.65006n	9.78051n	9.83712	9.93862	0.07687n	9.37286	9.32858n	9.49917	9.61473	9.93095n	9.87875n	9.98011	9.49481	9.22522n	9.84996	9.65087	0.07148n	9.31016	8.74126n	9.99065
Item	δ.	50 21 0	199 4.4	1.42319	9.02382	9.25270n	8.81017	9.51102	9.63876n	9.81175n	9.80162	9.95238	9.68761n	9.39108	9.34576n	9.49988	9.64903	9.91942n	9.90513n	9.94629	9.50724	9.25608n	9.84972	9.69195	0.05957n	9.31975	8.84017n	9.98919
Item	δ.	50 28 0	200 38.4	1.70846	9.03989	9.26510n	8.77612	9.53905	9.62065n	9.83938n	9.76424	9.96799	9.59186n	9.40338	9.36509n	9.49154	9.68500	9.90614n	9.93667n	9.91203	9.51806	9.29334n	9.84653	9.73512	[illegible]	9.32984	8.95278n	9.98801
Item	δ.	50 59 0	203 17.4	1.71435	9.08008	9.28522n	8.74757	9.57778	9.59175n	9.87063n	9.68640	9.97026	9.35366n	9.42751	9.39172n	9.48516	9.73236	9.88160n	9.96882n	9.83991	9.53579	9.34200n	9.84345	9.79045	0.02596n	9.34436	9.07307n	9.98591
Item	δ.	51 46 0	207 24.4	1.30840	9.13742	9.31293n	8.68105	9.62894	9.53240n	9.90344n	9.50773	9.96449	8.51325	9.46231	9.42994n	9.47132	9.79457	9.83294n	0.00423n	9.68042	9.56121	9.41001n	9.83692	9.86223	9.98178n	9.36504	9.21924n	9.98163
Item	δ.	53 0 0	210 4.4	1.33398	9.20034	9.33228n	8.72438	9.65302	9.49966n	9.90216n	9.32788	9.91910	9.22295	9.49369	9.44670n	9.48139	9.81841	9.79776n	9.99993n	9.53932	9.57865	9.43730n	9.83856	9.88687	9.94414n	9.37522	9.27419n	9.97913
New Archangelsk	z.	57 2 44	224 34 44	1.22866n	9.04232n	9.65117n	9.64479n	8.08654	9.91922	9.66921	9.68830n	9.04160n	8.10955	9.54327	9.89781n	9.88643n	8.16429	9.99697	9.04849	9.66765n	0.04621	9.98016n	9.98278n	8.11554	9.98822	0.22484	9.88920n	9.88288n
Pacific	z.	54 26 41	221 1 18	1.08243	9.33771n	9.61946n	9.55895n	9.08444	9.93963	9.63985	9.82625n	9.74260n	9.19517	9.30395	9.90876n	9.84835n	9.18274	0.03733	9.63255	9.81895n	9.99370	0.02969n	9.96918n	9.14740	[illegible]	0.21142	9.94321n	9.88270n
Item	z.	43 18 29	230 5 6	1.75450	9.68216n	8.82686n	8.90435n	9.18514n	9.93136	0.05970	9.81666n	0.11370n	9.68779n	9.55065n	9.70345n	9.78094n	9.40912n	0.15534	0.12652	9.88348n	9.61433	9.98263n	0.06012n	9.44791n	0.19413	0.13730	9.97027n	0.04776n
Item	z.	40 3 25	233 20 38	1.88497	9.68909n	8.32630	8.45461	9.35835n	9.88151	0.13228	9.66263n	0.15621	0.07499n	9.67979n	9.59257n	9.72088n	9.63657n	0.15973	0.22681	9.87216n	9.38466	9.94558n	0.07389n	9.70305n	0.22621	0.10961	9.96091n	0.08927n
Item	z.	39 12 9	235 9 43	1.97557	9.68625n	8.60916	8.76657	9.42755n	9.85890	0.15315	9.57040n	0.13670n	0.06085n	9.75491n	9.54809n	9.70550n	9.72206n	0.15341	0.25548	0.07273n	9.29778	9.92396n	0.08137n	9.79636n	0.22771	0.10179	9.04711n	0.10452n
Item	z.	38 0 13	235 25 36	1.19645	9.67903n	8.83315	8.99481	9.41678n	9.83593	0.16570	9.55295n	0.15880n	0.10804n	9.73563n	9.50562n	9.66728n	9.73589n	0.15504	0.27901	9.66666n	9.13767	9.91696n	0.07862n	9.82157n	[illegible]	0.09041	9.95149n	0.11315n
San Francisco	z.	37 48 44	237 35 24	1.68224	9.67741n	8.83522	9.03254	9.49050n	9.81827	0.17593	9.79920n	0.06492n	0.17606n	9.74011n	9.47407n	9.67134n	9.81372n	0.14149	0.29151	9.39484n	9.10585	9.89141n	0.08873n	9.90127n	[illegible]	0.08854	9.92781n	0.12513n
Pacific	z.	31 50 34	234 14 56	1.91840	9.57632n	9.29373	9.43644	9.19607n	9.66619	0.18876	9.68093n	[illegible]	0.19504n	9.83173n	9.19191n	9.33462n	9.68412n	0.15964	0.36955	9.86172n	9.21730n	[illegible]	0.03790n	9.83688n	0.31240	0.02333	9.99680n	0.13951n
Item	z.	30 31 20	235 38 0	2.01914	9.53683n	9.32366	9.48870	9.18996n	9.59997	0.19894	9.56575n	[illegible]	0.26982n	9.84192n	9.05187n	9.21691n	9.73781n	0.14761	0.39628	9.76311n	9.35448n	9.80069n	0.03479n	9.90712n	0.31063	0.00678	[illegible]	0.15294n
Item	z.	29 3 53	238 19 3	2.04602	9.48341n	9.33190	9.54148	9.20777n	9.56255	0.20840	9.15446n	0.24190n	0.36904n	9.84962n	8.82024n	0.02982n	9.82318n	0.12296	0.42503	9.57109n	9.46538n	9.82546n	0.03504n	0.01178n	0.31150	9.98749	9.96291n	0.17249n
Item	z.	28 40 58	238 55 9	1.99414	9.46741n	9.33329	9.55313	9.19657n	9.47386	0.20890	8.96724n	[illegible]	0.38845n	9.85104n	8.74040n	8.96024n	9.83883n	0.11612	0.43079	9.18513n	9.48983n	9.81433n	0.03417n	0.03269n	0.30998	9.98223	9.95703n	0.17687n
Item	z.	28 4 9	239 3 16	2.09823	9.43967n	9.34373	9.56588	9.15856n	9.43090	0.20800	8.90301n	0.22670n	0.40127n	9.85231n	8.58910n	8.81125n	9.83911n	0.11145	0.43850	0.13354n	9.52619n	9.80653n	0.02868n	0.04158n	0.31792	9.97362	9.95785n	0.18000n
New Archangelsk	y.	57 2 44	224 34 44	0.93095	−∞	9.21024n	9.21662	9.78573	7.95293n	9.73095n	9.71179n	[illegible]	9.80860	−∞	9.54878n	9.53516	9.96[illegible]37	8.12759n	9.80713	9.77797n	−∞	9.77009n	9.77647	0.03656	8.70378n	−∞	9.84621n	9.85263
Pacific	y.	54 26 41	221 1 18	0.79796	−∞	9.09544n	9.15595	9.77655	8.92196n	9.83980n	9.65347	9.33372	9.87871	−∞	9.48165n	9.54221	9.97176	9.11717n	9.92947n	9.74307n	−∞	9.72752n	9.78863	0.06137	9.20608n	−∞	9.81713n	9.87764
Item	y.	43 18 29	230 5 6	1.06221	−∞	8.34344n	8.26595	9.67143	8.92526	9.73287n	9.97591n	9.72891n	9.15992	−∞	9.31695n	9.23916	9.99236	9.24615	9.89662n	0.13964n	−∞	9.72106n	9.64357	0.15609	9.40988	−∞	9.88479n	9.80730
Item	y.	40 3 25	233 20 38	0.26482	−∞	7.87175	7.74344n	9.59967	9.07669	9.58691n	0.02656n	9.99410	0.17546	−∞	9.23504n	9.10673	9.97480	9.45182	9.77833n	0.01798n	−∞	9.71288n	9.58457	0.16622	9.64324	−∞	9.90430n	9.77508
Item	y.	39 12 9	235 25 36	1.28691n	−∞	8.17834	8.02093n	9.57171	9.14038	9.45029n	0.04204n	0.08360n	0.14991	−∞	9.21418n	9.05677	9.96313	9.53180	9.65853n	0.24198n	−∞	9.71499n	9.55758	0.16237	9.73104	−∞	9.91422n	9.75685
Item	y.	38 0 13	237 35 24	1.36624n	−∞	8.39933	8.23767n	9.54148	9.12233	9.43459n	0.04694n	0.11362n	0.16466	−∞	9.16871n	9.00705	9.95750	9.53835	9.64521n	0.25756n	−∞	9.70499n	9.54333	0.16812	9.74857	−∞	9.91561n	9.75394
San Francisco	y.	37 48 44	234 14 56	1.04532n	−∞	8.43593	8.23861n	9.54269	9.19491	9.15977n	0.05644n	0.18151n	0.09977	−∞	9.17174n	8.97432	9.94283	9.61499	9.37226n	0.26893n	−∞	9.71397n	9.51665	0.15532	9.82748	−∞	9.92640n	9.72914
Pacific	y.	31 50 34	235 38 0	1.58894n	−∞	8.80831	8.66560n	9.33910	8.86556	9.52992n	0.03775n	0.16890n	0.29192	−∞	8.80340n	8.66069	9.92946	9.45392	9.80762n	0.31545n	−∞	9.63162n	9.48891	0.20716	9.77162	−∞	9.90932n	9.76661
Item	y.	30 31 20	238 19 3	1.64266n	−∞	8.85451	8.68947n	9.26661	8.85680	9.40868n	0.04187n	0.23760n	0.27513	−∞	8.67963n	8.51459	9.91137	9.50156	9.70292n	0.33611n	−∞	9.62244n	9.45740	0.20562	9.70581	−∞	9.91669n	9.75165
Item	y.	29 3 53	238 55 9	1.81411n	−∞	8.90096	8.69138n	9.16300	8.86329	8.99107n	0.04499n	0.33059n	0.20344	−∞	8.48621n	8.27663	9.88032	9.58061	9.30461n	0.35853n	−∞	9.61637n	9.40678	0.19386	9.86415	−∞	9.97991n	9.72033
Item	y.	28 40 58	239 3 16	1.77166n	−∞	8.91102	8.69118n	9.13278	8.85549	8.79827n	0.04391n	0.34840n	0.18266	−∞	8.41503n	8.19519	9.87195	9.59466	9.11706n	0.36270n	−∞	9.61390n	9.39406	0.19075	9.91246	−∞	9.93170n	9.71286
Item	y.	28 4 9	224 34 44	1.60563n	−∞	8.92125	8.69910n	9.08731	8.81497	8.73553n	0.04049n	0.38871n	0.18414	−∞	8.26382n	8.04167	9.86477	9.59243	9.06294n	0.36790n	−∞	9.60590n	9.38375	0.19218	9.91084	−∞	9.93331n	9.71185
New Archangelsk	x.	57 2 44	221 1 18	1.27231n	9.70162	9.33585n	9.32949n	7.55138n	9.38416n	9.57006n	9.58922	9.75241	8.20087n	9.91521	8.71957n	8.71319n	7.94896n	9.78174n	9.71194n	9.73095	9.96042	9.46351	9.45713	8.12759n	9.06077n	9.73558	9.77647	9.77009
Pacific	x.	54 26 41	230 5 6	0.80618n	9.64491	9.44823n	9.38772n	8.37455n	9.22915n	9.48277n	9.66917	9.78610	9.24411n	9.90618	9.11923n	9.05872n	8.89965n	9.75404n	9.65345n	9.83986	9.97595	9.78786	9.32735	9.11717n	9.07176n	9.76454	9.78803	9.72762
Item	x.	43 18 29	233 20 38	9.43136	8.92265	9.50690n	9.58439n	8.55124n	9.29745	9.60796n	9.36492	9.99619	9.56521	9.77122	9.54039n	9.61788n	8.72318	9.46939n	9.97591n	9.73287	9.99924	8.57833n	8.65583n	9.74615	9.09236n	9.86164	0.01357	9.72166

Stations and observed elements.	Latitude. ° ′ ″	Long. East, Greenwich. ° ′ ″	Log. n.	Log. coef. $\Delta g^{4,0}$.	Log. coef. $\Delta g^{4,1}$.	Log. coef. $\Delta h^{4,1}$.	Log. coef. $\Delta g^{4,2}$.	Log. coef. $\Delta h^{4,2}$.	Log. coef. $\Delta g^{4,3}$.	Log. coef. $\Delta h^{4,3}$.	Log. coef. $\Delta g^{4,4}$.	Log. coef. $\Delta h^{4,4}$.	Log. coef. $\Delta g^{3,0}$.	Log. coef. $\Delta g^{3,1}$.	Log. coef. $\Delta h^{3,1}$.	Log. coef. $\Delta g^{3,2}$.	Log. coef. $\Delta h^{3,2}$.	Log. coef. $\Delta g^{3,3}$.	Log. coef. $\Delta h^{3,3}$.	Log. coef. $\Delta g^{2,0}$.	Log. coef. $\Delta g^{2,1}$.	Log. coef. $\Delta h^{2,1}$.	Log. coef. $\Delta g^{2,2}$.	Log. coef. $\Delta h^{2,2}$.	Log. coef. $\Delta g^{1,0}$.	Log. coef. $\Delta g^{1,1}$.	Log. coef. $\Delta h^{1,1}$.
Pacific .... x.	41 3 25	233 20 38	0·94399n	8·45340n	9·45975n	9·58806n	8·94950n	9·47248	9·55818n	9·11853	9·98404	9·80277	9·69175	9·56572n	9·69403n	8·72687	9·24985n	0·02656n	9·58691	9·99350	9·01072n	9·13904n	9·45182	9·97480n	9·88389	9·58457	9·71288
Item .... x.	39 12 9	235 9 43	0·24797	8·75542n	9·43256n	9·58997n	9·06817n	9·49950	9·54087n	8·95812	9·94967	9·88345	9·66633	9·55823n	9·71564n	8·72779	9·15912n	0·04204n	9·45929	9·99105	9·06003n	9·21740n	9·53180	9·96313n	9·88926	9·55758	9·71499
Item .... x.	38 0 13	235 25 36	0·87448n	8·98229n	9·41557n	9·57723n	9·12342n	9·54257	9·49343n	8·88108	9·95404	9·90300	9·62672	9·56974n	9·73140n	8·58561	9·04476n	0·04694n	9·43459	9·98692	9·13741n	9·29908n	9·53835	9·95750n	9·89651	9·54333	9·70499
San Francisco .... x.	37 48 44	237 35 24	1·46598n	9·00917n	9·38777n	9·58500n	9·20731n	9·53515	9·49377n	8·59710	9·88728	9·96902	9·61994	9·54700n	9·74432n	8·63730	8·96014n	0·05644n	9·15977	9·98618	9·12408n	9·32140n	9·61499	9·94283n	9·89764	9·51665	9·71397
Pacific .... x.	31 50 34	234 14 56	0·64444	9·43021n	9·29187n	9·43458n	9·22192n	9·69746	8·89306n	8·38523	0·01422	9·89127	9·30036	9·62402n	9·76673n	8·64789n	9·12313	0·03775n	9·52992	9·95249	9·41331n	9·55602n	9·45392	9·92940n	9·92916	9·48891	9·63162
Item .... x.	30 31 20	235 38 0	1·42504	9·47510n	9·22906n	9·39410n	9·29882n	9·70863	8·36060n	7·72741	9·98083	9·94344	9·17528	9·61158n	9·77662n	8·84927n	9·25908	0·04187n	9·40868	9·94205	9·43662n	9·60166n	9·50156	9·91137n	9·93522	9·45740	9·67244
Item .... z.	25 59 12	238 47 41	2·02572	9·32201n	9·38271	9·60041	8·96337n	9·24532	0·20086	9·00123n	0·27055n	0·42812n	9·85435n	8·17436	8·39206	9·81683n	0·09868	0·46232	9·26269n	9·62743n	9·78688n	0·00458n	0·05026n	0·33211	9·94266	9·96916n	0·18686n
Item .... z.	23 6 12	238 7 32	2·08027	9·05212n	9·41776	9·62409	8·31777n	8·62479	0·18166	9·17807n	0·33818n	0·45320n	9·84514n	8·95147	9·15780	9·76887n	0·07589	0·49193	9·48534n	9·73085n	9·75721n	9·96354n	0·05021n	0·35723	9·89475	9·98740n	0·19373n
Item .... z.	20 21 34	237 44 6	2·00617	8·24674n	9·42774	9·62749	8·61528	8·03738n	0·15331	9·22942n	0·38653n	0·47702n	9·82383n	9·19886	9·39861	9·72098n	0·04308	0·51494	9·59105n	9·80406n	9·71797n	9·91772n	0·05458n	0·37608	9·84249	0·00042n	0·20017n
Item .... z.	18 36 21	237 27 24	1·96204	8·64444	9·42450	9·61959	8·89029	9·22333n	0·12901	9·25600n	0·41537n	0·48884n	9·80334n	9·30158	9·49667	9·68383n	0·01687	0·52823	9·65522n	9·84173n	9·68840n	9·88349n	0·05502n	0·38800	9·80490	0·00844n	0·20353n
Item .... z.	16 5 30	236 57 12	1·97539	9·10992	9·40726	9·59398	9·09171	9·44504n	0·08409	9·29620n	0·45661n	0·49933n	9·76346n	9·41185	9·59857	9·68781n	9·97114	0·54443	9·75096n	9·88622n	9·63916n	9·82588n	0·05012n	0·40345	9·74378	0·02032n	0·20704n
Item .... z.	12 24 19	236 21 6	1·91461	9·38274	9·34695	9·52373	9·25042	9·62885n	9·99230	9·27871n	0·50431n	0·51048n	9·67754n	9·52245	9·69923	9·50016n	9·87859	0·56331	9·84972n	9·93527n	9·54252n	9·71930n	0·04314n	0·42117	9·63311	0·03135n	0·21113n
Item .... y.	25 59 12	238 47 41	1·35603n	−∞	8·94773	8·73003n	8·89357	8·61172	8·82567n	0·02550n	0·37750n	0·21993	−∞	7·83629	7·61850n	9·84394	9·56209	9·18404n	0·38367n	−∞	9·57375n	9·35605	0·20231	9·92040	−∞	9·93212n	9·71442
Item .... y.	23 6 12	238 7 32	1·75831n	−∞	8·96142	8·75510n	8·26316	7·95614	8·98953n	9·99612n	0·39260n	0·27758	−∞	8·59205	8·38572n	9·81117	9·50415	9·39581n	0·40240n	−∞	9·52272n	9·31640	0·21745	9·91043	−∞	9·92900n	9·72268
Item .... y.	20 21 34	237 44 6	1·78654n	−∞	8·95654	8·75679n	8·56746n	8·24536n	9·03559n	9·95948n	0·40813n	0·31744	−∞	8·82457	8·62482n	9·77007	9·44797	9·49413n	0·41802n	−∞	9·46862n	9·26887	0·22861	9·90651	−∞	9·92716n	9·72741
Item .... y.	18 36 21	237 27 24	1·80936n	−∞	8·94394	8·74885n	8·84871n	8·51567n	9·05747n	9·93048n	0·41525n	0·34173	−∞	8·91793	8·72284n	9·73916	9·40612	9·55360n	0·42661n	−∞	9·42969n	9·23460	0·23529	9·90215	−∞	9·92582n	9·73073
Item .... y.	16 5 30	236 57 12	1·81458n	−∞	8·91237	8·72565n	9·06446n	8·71113n	9·08613n	9·87960n	0·41978n	0·37706	−∞	9·01387	8·82715n	9·68747	9·33414	9·64338n	0·43685n	−∞	9·36612n	9·17940	0·24472	9·89019	−∞	9·92337n	9·73665
Item .... y.	12 24 19	236 21 6	1·82743n	−∞	8·83502	8·65824n	9·24117n	8·86274n	9·06712n	9·78071n	0·42183n	0·41766	−∞	9·10743	8·93065n	9·58782	9·20939	9·73504n	0·44863n	−∞	9·25444n	9·07566	0·25574	9·87751	−∞	9·92036n	9·74258
Item .... x.	25 59 12	238 47 41	1·39585	9·57138n	8·93056n	9·14826n	9·44227n	9·72413	9·27219	8·07256n	9·86156	9·91913	8·33500n	9·56666n	9·78436n	9·24686n	9·52871	0·02530n	8·82567	9·89637	9·50404n	9·72174n	9·56209	9·84394n	9·95371	9·35605	9·57355
Item .... x.	23 6 12	238 7 32	1·37749	9·59817n	8·57068n	8·77700n	9·42579n	9·73281	9·50974	8·50415n	9·87130	9·98632	9·10385n	9·55668n	9·76300n	9·34005n	9·64707	9·99612n	8·98953	9·85844	9·56282n	9·76914n	9·50415	9·81117n	9·96369	9·31640	9·52272
Item .... x.	20 21 34	237 44 6	1·49248	9·60342n	8·03190	8·23165	9·40259n	9·72469	9·65351	8·71952n	9·85890	9·94959	9·34651n	9·53295n	9·73270n	9·40954n	9·73164	9·95948n	9·03559	9·81447	9·60704n	9·80679n	9·44797	9·77007n	9·97198	9·26887	9·46862
Item .... x.	18 36 21	237 27 24	1·64885	9·59686n	8·61925	8·81434	9·37890n	9·71191	9·72720	8·84939n	9·84560	9·91912	9·44591n	9·51212n	9·70721n	9·44295n	9·77599	9·93048n	9·05747	9·78158	9·63187n	9·82696n	9·40612	9·73916n	9·97668	9·23460	9·42969
Item .... x.	16 5 30	236 57 12	1·48926	9·57370n	8·92930	9·11662	9·32942n	9·68275	9·80027	9·00680n	9·81981	9·86251	9·55026n	9·47377n	9·66049n	9·47658n	9·82991	9·87960n	9·08613	9·72642	9·66420n	9·85092n	9·33414	9·68747n	9·98264	9·17940	9·36612
Item .... x.	12 24 19	236 21 6	1·51654	9·50646n	9·15696	9·33374	9·23080n	9·60923	9·88286	9·16920n	9·74974	9·75391	9·65393n	9·38985n	9·56663n	9·51155n	9·88998	9·78071n	9·06712	9·62285	9·70152n	9·87830n	9·20939	9·58789n	9·98974	9·07566	9·25244
Item .... x.	29 3 53	238 19 3	1·29358	9·51466n	9·13351n	9·34309n	9·40724n	9·70695	8·62960	7·57568n	9·88090	9·91705	8·97497	9·58055n	9·79014n	9·05850n	9·35821	0·04499n	8·99107	9·92903	9·44297n	9·65255n	9·58061	9·88032n	9·94155	9·40678	9·61637
Item .... x.	28 40 58	237 55 9	0·85733	9·52352n	9·10679n	9·32663n	9·42853n	9·70582	8·78129	7·56535n	9·86386	9·91960	8·90259	9·57272n	9·79256n	9·10225n	9·37954	0·04391n	8·79827	9·92537	9·44467n	9·66451n	9·59466	9·87100n	9·94314	9·39406	9·61390
Item .... x.	28 4 9	239 3 16	1·47188	9·53566n	9·07164n	9·29379n	9·43756n	9·70990	8·94913	7·64417n	9·85673	9·93130	8·75329	9·57008n	9·79223n	9·14488n	9·41722	0·04049n	8·73553	9·91928	9·45715n	9·67931n	9·59243	9·86477n	9·94566	9·38375	9·60590
Item .... z.	9 19 3	235 49 9	1·85612	9·50488	9·25668	9·42476	9·32106	9·72257n	9·88043	9·22761n	0·53802n	0·31194n	9·57008n	9·58589	9·75397	9·36652n	9·76803	0·57427	9·92145n	9·96443n	9·43017n	9·59825n	0·03733n	0·43364	9·51078	0·04483n	0·21291n
Item .... z.	6 51 21	236 24 54	1·89415	9·56644	9·13297	9·31079	9·39084	9·76658n	9·75882	9·03745n	0·57195n	0·40960n	9·44666n	9·61074	9·78856	9·26155n	9·63729	0·58503	9·86366n	9·98102n	9·29375n	9·47157n	0·05973n	0·43547	9·37791	0·04078n	0·21860n
Item .... z.	5 12 0	236 2 37	1·76118	9·59517	9·02518	9·19689	9·39980	9·79150n	9·64149	8·96410n	0·53998n	0·42600n	9·33153n	9·63018	9·80189	9·13096n	9·52266	0·58730	9·90991n	9·98917n	9·17969n	9·35740n	0·04874n	0·44044	9·25831	0·04632n	0·21803n
Item .... z.	2 41 46	234 6 3	1·64147	9·62237	8·76916	8·90933	9·34081	9·82386n	9·34889	8·85280n	0·60277n	0·47044n	9·05107n	9·66613	9·80630	8·76817n	9·25122	0·57957	0·08348n	9·99712n	8·91739n	9·05756n	9·97082n	0·45387	8·97344	0·06880n	0·20906n
Item .... z.	1 9 28	233 0 34	1·55883	9·63022	8·41526	8·53830	9·29332	9·83525n	8·97449	8·55799n	0·62684n	0·49330n	8·68520n	9·68147	9·80451	8·34830n	8·89023	0·57203	0·15553n	9·99947n	8·56194n	8·68498n	9·91781n	0·45974	8·60658	0·08030n	0·20332n
Item .... z.	− 0 3 53	231 19 22	1·57136	9·63200	7·17604n	7·27269n	9·19419	9·84321n	7·70582n	7·39458	0·65520n	0·52975n	7·43329	9·69892	9·79557	6·99568	7·64470n	0·55561	0·24487n	0·00000n	7·32625	7·42290	9·81744n	0·46646	7·35433n	0·09680n	0·19351n
Item .... z.	− 0 2 37	229 18 54	1·48230	9·63760	7·00451n	7·07017n	9·03011	9·84892n	7·49754n	7·29426	0·67896n	0·57130n	7·24944	9·71727	9·78293	6·64871	7·46552n	0·53022	0·32694n	0·00000n	7·16171	7·22737	9·65336n	0·47217	7·17144n	0·11521n	0·18087n
Item .... z.	− 0 53 23	228 3 18	1·39533	9·63094	8·34744n	8·39384n	8·88015	9·85057n	8·79891n	8·65754	0·68881n	0·62442n	8·57136	9·72757	9·77397	7·81429	8·78471n	0·51077	0·36940n	9·99969n	8·49335	8·53975	9·58412n	0·47451	8·49226n	0·12603n	0·17243n
Item .... z.	− 1 49 45	226 40 55	1·27138	9·62757	8·67028n	8·69570n	8·61743	9·84959n	9·08679n	9·01014	0·69511n	9·76348n	8·88355	9·73705	9·76247	7·87277	9·10493n	0·48585	0·40920n	9·99867n	8·81735	8·84277	9·24378n	0·47591	8·80508n	0·13721n	0·16263n
Item .... z.	− 1 52 14	225 5 1	1·37088	9·62731	8·69248n	8·69375n	7·31389	9·85016n	9·06342n	9·05963	0·69804n	0·46280n	8·89321	9·74938	9·75067	6·57910	9·11537n	0·45274	0·44895n	9·99861n	8·83951	8·84078	7·94639n	0·47666	8·81480n	0·13965n	0·15092n
Item .... z.	− 1 35 44	222 28 33	1·25648	9·62859	8·64320n	8·60493n	8·79705n	9·84947n	8·92692n	9·14307	0·69151n	9·42100	8·82452	9·76902	9·73071	7·99234n	9·04476n	0·38528	0·50143n	9·99898n	8·78948	8·75117	9·42267	0·47569	8·74576n	0·16866n	0·13035n
Item .... z.	− 2 20 19	220 30 57	0·97128	9·62485	8·82061n	8·75231n	9·04086n	9·84251n	9·02727n	9·23914	0·67583n	9·18603	8·98963	9·78004	9·71127	8·40486n	9·20671n	0·31965	0·53152n	9·99782n	8·96842	8·90015	9·66921	0·47166	8·91174n	0·18162n	0·11135n
Item .... z.	− 3 21 49	219 9 46	0·85794	9·61684	8·98479n	8·89569n	9·14785n	9·83271n	9·12941n	9·51312	0·65887n	0·29399	9·14625	9·78430	9·69520	8·67505n	9·35991n	0·26407	0·54778n	9·99549n	9·13430	9·04520	9·78168	0·46654	9·06946n	0·18978n	0·10068n
Item .... z.	− 5 1 40	218 9 25	1·25575	9·59764	9·15978n	9·05505n	9·20056n	9·81400n	9·25389n	9·59579	0·61068n	9·35481	9·31740	9·77999	9·67526	8·91546n	9·52892n	0·21425	0·55615n	9·98987n	9·31375	9·20902	9·84779	0·46125	9·24376n	0·19493n	0·09020n
Item .... z.	− 7 37 46	216 41 46	1·29159	9·54774	9·33610n	9·20837n	9·24503n	9·77046n	9·34635n	9·78518	0·60603n	9·42208	9·49032	9·76329	9·63556	9·17345n	9·69888n	0·12637	0·56320n	9·97642n	9·55045	9·37272	9·92544	0·45687	9·42410n	0·20129n	0·07356n
Item .... z.	−10 19 8	215 11 9	1·59329	9·47114	9·45614n	9·30436n	9·25515n	9·70202n	9·35996n	9·91528	0·55957n	9·57191	9·61000	9·73211	9·58033	9·36789n	9·81566n	0·00929	0·56461n	9·95593n	9·63618	9·48440	9·98919	0·43606	9·55479n	0·20633n	0·05455n
Item .... z.	−12 29 51	214 25 55	1·53643	9·37803	9·52189n	9·35790n	9·21756n	9·63029n	9·36442n	9·99096	0·54649n	9·68509	9·68015	9·69318	9·52919	9·47349n	9·88622n	9·93246	0·55900n	9·93424n	9·71831	9·55432	0·01330	0·42603	9·63628n	0·20697n	0·04298n
Item .... z.	−14 20 42	213 38 6	1·49471	9·26565	9·56454n	9·38754n	9·16953n	9·54739n	9·32863n	0·04383	0·48990n	9·49687	9·72737	9·65055	9·47355	9·55560n	9·93346n	9·83766	0·55286n	9·91108n	9·77782	9·60082	0·03662	0·41448	9·69506n	0·20770n	0·03070n
Item .... z.	−16 27 25	210 26 34	1·53832	9·06744	9·61055n	9·37972n	9·14632n	9·40054n	8·46239n	0·09658	0·34774n	9·55578	9·77006	9·59769	9·36686	9·70508n	9·95930n	8·91324	0·54743n	9·88037n	9·84676	9·61593	0·12790	0·38212	9·75327n	0·21843n	9·98760n
Taeiti, Point Venus .... z.	−17 29 17	210 29 54	1·85272	8·91514	9·62085n	9·39097n	9·06406n	9·32025n	8·53163n	0·11501	0·34090n	9·54522	9·78722	9·55701	9·32713	9·72444n	9·98063n	8·95688	0·54026n	9·86277n	9·86966	9·63978	0·12164	0·37583	9·77889n	0·21581n	9·98593n
Pacific .... z.	−19 6 18	209 52 55	1·91440	8·42894	9·63460n	9·39396n	8·90298n	9·13741n	7·93228	0·14027	0·29327n	9·54015	9·80972	9·48343	9·24279	9·76986n	0·00429n	8·32026n	0·52825n	9·83164n	9·90551	9·66487	0·12998	0·36441	9·81597n	0·21448n	9·97384n
Item .... z.	−23 34 0	209 48 47	1·36305	9·10975n	9·63428n	9·39245n	8·55745	8·78940	8·17737	0·18735	0·23671n	9·48844	9·84974	9·10627	8·86444	9·83211n	0·06416n	8·47860n	0·48858n	9·71637n	9·97949	9·73766	0·10531	0·33736	9·90289n	0·20155n	9·95972n
Item .... z.	−27 19 17	210 2 10	1·59890	9·44226n	9·58506n	9·34714n	9·12551	9·36537	7·47534n	0·22666	0·19438n	9·43038	9·85418	8·51622n	8·27830n	9·85917n	0·09897n	7·71663	0·44795n	9·56582n	0·02492	9·78700	0·07238	0·31223	9·96283n	0·18703n	9·94911n
Item .... z.	−28 55 47	213 24 32	1·11561n	9·47092n	9·54012n	9·35940n	9·12751	9·49584	9·55897n	0·20267	0·30899n	9·32967	9·85075	8·96540n	8·78468n	9·76505n	0·13338n	9·77974	0·42345n	9·48480n	0·02378	9·84306	9·95779	0·32012	9·98335n	0·16537n	9·98465n
Item .... z.	−30 32 49	213 6 55	1·21696	9·53769n	9·49382n	9·30824n	9·23696	9·59308	9·42087n	0·20457	0·26876n	9·30732	9·84176	9·22594n	9·04036n	9·78373n	0·13985n	9·61789	0·40159n	9·35230n	0·04133	9·85575	9·95272	0·30884	0·00710n	0·15917n	9·97359n
Item .... z.	−33 53 27	216 42 58	1·62890n	9·62392n	9·33889n	9·21153n	9·21778	9·74433	9·73986n	0·17527	0·29842n	9·11315	9·80939	9·47024n	9·34288n	9·64170n	0·16825n	9·89661	0·33202n	8·82717n	0·04655	9·91919	9·77042	0·29697	0·04737n	0·12412n	9·99676n
Item .... z.	−35 22 30	220 19 45	1·76886n	9·64953n	9·22561n	9·15448n	9·01605	9·79987	9·90738n	0·12882	0·32094n	9·85096	9·78769	9·52640n	9·45527n	9·39780n	0·18162n	0·04783	0·26929n	7·73719	0·03326	9·96213	9·51024	0·29406	0·06365n	0·09455n	0·02342n
Item .... z.	−37 38 58	218 18 11	1·69082n	9·67614n	9·02236n	8·91998n	9·22412	9·84633	9·80513n	0·13824	0·24403n	9·94719	9·74382	9·63366n	9·53120n	9·54996n	0·17317n	9·92231	0·25542n	9·08057	0·05635	9·95389	9·63911	0·26232	0·08694n	0·09435n	9·99189n
Item .... z.	−42 4 18	218 57 56	2·08507n	9·68815n	8·59605	8·50390	9·24637	9·91029	9·79231n	0·08711	0·14155n	9·79298	9·60724	9·75952n	9·66737n	9·48970n	0·15962n	9·86929	0·16409n	9·53022	0·06454	9·97239	9·53865	0·20857	0·12714n	0·06234n	9·97019n
Item .... z.	−44 45 18	223 49 44	2·04922n	9·66955n	9·08306	9·06531	8·56049	9·94884	9·92173n	9·97512	0·10284n	9·01624	9·46793	9·78245n	9·76470n	8·76362n	0·15197n	9·97720	0·03059n	9·67768	0·03425	0·01650	8·79106	0·17941	0·14865n	0·01054n	9·99279n
Item .... z.	−45 4 59	228 38 4	1·76095n	9·66586n	9·08075	9·13600	9·05334n	9·94779	0·01373n	9·84427	0·08023n	9·49414n	9·44573	9·75027n	9·80552n	9·25213	0·14638n	0·06670	9·89724n	9·70279	9·99620	0·05145	9·27707n	0·17132	0·15115n	9·96999n	0·02524n
Item .... z.	−47 13 25	237 49 32	1·88711n	9·63351n	9·16520	9·36647	9·59686n	9·91544	0·05773n	9·11596	9·82284n	9·91915n	9·25460	9·69023n	9·89150n	9·76806	0·08662n	0·09512	9·15335n	9·78978	9·90110	0·10237	9·77742n	0·09598	0·16673n	9·85931n	0·06058n
Item .... z.	−48 30 36	244 11 51	1·15473n	9·60423n	9·15581	9·47144	9·75593n	9·85697	0·02646n	9·37553n	9·34261n	9·97204n	9·06625	9·61967n	9·93530n	9·91209	0·01313n	0·05502	9·40409	9·83467	9·81159	0·12722	9·91262n	0·01366	0·17556n	9·76097n	0·07660n

Stations and observed elements.	Latitude.	Long. East, Greenwich.	Log. n.	Log. coef. $\Delta g^{4,0}$.	Log. coef. $\Delta g^{4,1}$.	Log. coef. $\Delta h^{4,1}$.	Log. coef. $\Delta g^{4,2}$.	Log. coef. $\Delta h^{4,2}$.	Log. coef. $\Delta g^{4,3}$.	Log. coef. $\Delta h^{4,3}$.	Log. coef. $\Delta g^{4,4}$.	Log. coef. $\Delta h^{4,4}$.	Log. coef. $\Delta g^{3,0}$.	Log. coef. $\Delta g^{3,1}$.	Log. coef. $\Delta h^{3,1}$.	Log. coef. $\Delta g^{3,2}$.	Log. coef. $\Delta h^{3,2}$.	Log. coef. $\Delta g^{3,3}$.	Log. coef. $\Delta h^{3,3}$.	Log. coef. $\Delta g^{2,0}$.	Log. coef. $\Delta g^{2,1}$.	Log. coef. $\Delta h^{2,1}$.	Log. coef. $\Delta g^{2,2}$.	Log. coef. $\Delta h^{2,2}$.	Log. coef. $\Delta g^{1,0}$.	Log. coef. $\Delta g^{1,1}$.	Log. coef. $\Delta h^{1,1}$.
Pacific ... z.	−51 2 26	252 38 48	0·62118n	9·52459n	9·10868	9·61382	9·87529n	9·71578	9·88201n	9·77388n	9·43889	0·86415n	8·41673n	9·48225n	9·98742n	0·00466	9·84515n	9·89433	9·78620	9·91068	9·64095	0·14612	9·98895n	9·82944	0·19180n	9·57409n	0·07926n
Item ... z.	−55 3 0	266 42 15	1·35199	9·28623n	8·51520	9·75598	9·93562n	8·99842	9·12115n	9·88025n	9·71957	[illegible]	9·37195n	8·79240n	0·03318n	0·02891	9·09171n	9·11091	9·86971	0·00668	8·96730	0·14868	9·99234n	[illegible]	0·21466n	8·81758n	0·05836n
Item ... z.	56 28 30	276 54 55	1·51388	9·13049n	8·86828n	9·78449	9·91259n	9·30384n	9·39575	9·81737n	9·61499	9·33441	9·50062n	9·11941	0·03562n	9·99463	9·38588	9·37786n	9·79948	0·03540	[illegible]	0·13711	9·94871n	9·33996n	0·22201n	9·12383	[illegible]
Item ... z.	−56 5 8	284 56 50	1·65070	9·18055n	9·19122n	9·76478	9·86721n	9·62680n	[illegible]	9·70846n	9·38493	9·62270	9·46886n	9·44919	0·02275n	9·95226	9·71185	9·69014n	9·69254	0·02779	9·55423n	0·12779	9·90831n	9·66790n	[illegible]	9·48913	[illegible]
Item ... z.	−58 31 12	289 57 14	0·86747n	8·63998n	9·35605n	9·79608	9·78623n	9·70863n	9·72028	9·48412n	[illegible]	9·56343	9·63781n	9·57506	0·01509n	9·85343	9·77583	9·69751n	9·45635	0·07261	[illegible]	0·09803	9·70763n	9·72003n	0·23189n	9·55195	9·99198n
Item ... z.	−56 21 30	299 34 22	0·81491	9·14782n	9·47867n	9·72475	9·63653n	9·86026n	9·84976	8·19977n	9·34869n	9·61773	9·49142n	9·73181	9·97789n	9·71946	9·94319	9·83245n	8·18246	0·03314	9·83433n	[illegible]	9·64412n	[illegible]	0·22143n	9·73784	9·98392n
Atlantic ... z.	51 28 19	304 46 58	1·29336	9·50732n	9·40644n	9·56472	9·50211n	9·93089n	9·96194	9·36971	9·75539n	9·69246	8·57426n	9·76760	9·92588n	9·62731	[illegible]	9·97166n	[illegible]	9·92220	9·93114n	[illegible]	9·60896n	0·03774n	0·19440n	9·85168	[illegible]
Item ... z.	47 10 42	306 46 24	0·02119n	9·63312n	9·21287n	9·33933	9·41250n	9·94219n	0·03343	[illegible]	[illegible]	[illegible]	9·26007	9·74013	9·86089n	9·58425	0·11324	0·07114n	9·03971n	[illegible]	[illegible]	[illegible]	9·59393n	0·12362n	0·16641n	9·91054	[illegible]
Item ... z.	−41 26 39	308 22 17	1·85040n	9·68962n	8·09179n	8·19318	9·27925n	9·90709n	[illegible]	9·77206	[illegible]	[illegible]	9·63709	9·64660	[illegible]	9·53294	[illegible]	0·18342n	9·85436n	9·49742	9·96567n	[illegible]	9·58721n	0·21505n	0·12182n	9·96879	[illegible]
Item ... z.	−37 43 4	309 47 54	1·68431n	[illegible]	8·92493	9·00422n	9·11639n	9·85253n	[illegible]	[illegible]	[illegible]	9·84222	9·74225	9·54772	[illegible]	9·44169	[illegible]	0·23077n	9·98756n	9·08927	9·96814n	[illegible]	9·55016n	0·20630n	[illegible]	[illegible]	[illegible]
Item ... z.	34 24 27	311 26 26	1·78233n	[illegible]	9·22670	[illegible]	8·86930n	9·77270n	0·11741	9·95165	[illegible]	[illegible]	9·80236	9·41597	9·47006n	9·28025	0·18375	0·26839n	0·10263n	8·62380n	9·96646n	0·02055	[illegible]	[illegible]	0·05314n	[illegible]	[illegible]
Item ... z.	−28 55 46	314 9 52	1·69170n	[illegible]	9·45783	9·47050n	8·00759n	9·54260n	[illegible]	[illegible]	[illegible]	9·23311	[illegible]	8·91831	8·03101n	8·03571	0·17071	0·29610n	0·25805n	9·47483n	9·94690n	9·95957	8·82617n	[illegible]	9·98563n	0·08621	0·09885n
Item ... z.	−26 22 0	315 46 7	1·63599n	9·34674n	9·51823	9·50659n	7·76731	9·33875n	[illegible]	[illegible]	[illegible]	9·23741n	9·85460	7·85206n	7·84042	8·58253n	0·15397	0·39022n	0·32520n	9·61098n	9·93213n	9·92039	8·81010	0·38154n	9·94852n	0·16855	0·09691n
Item ... z.	24 12 12	316 35 34	1·65050n	9·17768n	9·54881	9·52465n	7·76557	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9·85023	8·92739n	[illegible]	8·87967n	0·13423	0·29225n	0·36501n	9·60536n	9·91114n	9·38698	9·14197	0·39653n	9·91379n	0·13330	0·09914n
Rio de Janeiro ... z.	−22 53 54	316 55 3	1·30771n	[illegible]	9·55993	9·53033n	7·39194	8·55813n	9·98236	[illegible]	[illegible]	0·66923n	9·84398	9·11684n	[illegible]	8·95363n	0·11983	0·29539n	0·38473n	9·73702n	9·89532n	[illegible]	9·23863	0·40483n	[illegible]	0·12917	0·09957n
Pacific ... y.	9 19 7	235 49 9	1·70509n	∞	8·73174	8·56348n	9·33040n	8·92889n	[illegible]	9·66435n	[illegible]	34688	−∞	9·15768	8·98958n	9·47277	9·07126	9·80228n	[illegible]	−∞	9·12690n	8·95882	0·26352	[illegible]	−∞	9·91765n	[illegible]
Item ... y.	6 51 21	236 24 54	1·79167n	∞	8·61493	8·43711n	9·37175n	8·99001n	8·81871n	9·51008n	[illegible]	43715	−∞	9·18061	9·01179n	9·33937	8·96363	9·74183n	[illegible]	−∞	[illegible]	8·81074	0·26249	[illegible]	−∞	9·92068n	9·74286
Item ... y.	5 12 0	236 2 37	1·82439n	−∞	8·49971	8·32800n	9·39535n	9·00365n	8·74404n	[illegible]	[illegible]	44484	−∞	9·20107	9·02091n	9·22347	8·83172	9·78676n	0·46415n	−∞	[illegible]	8·70436	0·26614	9·87444	−∞	9·91879n	9·74708
Item ... y.	2 41 46	234 6 3	1·76080n	−∞	8·21084	8·07067n	9·42540n	8·94335n	[illegible]	9·12752n	[illegible]	[illegible]	−∞	9·20472	9·04455n	8·95067	8·46762	[illegible]	0·45511n	−∞	[illegible]	[illegible]	0·27826	9·79521	−∞	9·90851n	9·76834
Item ... y.	1 9 28	233 0 34	1·73014n	−∞	7·83942	7·71638n	9·43740n	[illegible]	8·53633n	8·75273n	[illegible]	[illegible]	−∞	9·20254	[illegible]	8·58929	8·04736	[illegible]	0·44718n	−∞	[illegible]	[illegible]	0·28374	[illegible]	−∞	9·90220n	[illegible]
Item ... y.	−0 3 53	231 19 22	1·61225n	−∞	6·57372n	6·47707	[illegible]	8·79615n	[illegible]	[illegible]	[illegible]	55829	−∞	9·19351	9·09686n	7·34367n	6·69465n	0·11043n	[illegible]	−∞	6·94578	6·84913n	0·29637	9·64135	−∞	9·89248n	9·79583
Item ... y.	0 2 37	229 18 54	1·66857n	−∞	6·37120n	[illegible]	9·45098n	[illegible]	[illegible]	[illegible]	[illegible]	58205	−∞	9·18087	9·11521n	7·16449n	[illegible]	[illegible]	0·40528n	−∞	6·75025	6·68459n	0·29408	9·47727	−∞	9·87984n	[illegible]
Item ... y.	−0 53 23	228 3 18	1·65543n	−∞	7·69492n	7·64852	9·45768n	8·48226n	8·43574	[illegible]	[illegible]	59195	−∞	[illegible]	9·12556n	[illegible]	7·51531n	[illegible]	0·38588n	−∞	[illegible]	8·01628n	0·29250	[illegible]	−∞	9·87143n	[illegible]
Item ... y.	−1 49 45	226 40 35	1·69170n	−∞	7·99695n	7·97153	[illegible]	8·21971n	8·78853	8·86518	[illegible]	59842	−∞	[illegible]	9·13521n	8·80412n	7·57196n	[illegible]	[illegible]	−∞	8·36387	8·34045n	0·30007	[illegible]	−∞	9·86182n	[illegible]
Item ... y.	−1 52 14	225 5 1	1·64008n	∞	7·99501n	7·99574	9·45245n	6·91678n	[illegible]	[illegible]	[illegible]	[illegible]	−∞	9·14882	9·14755n	8·81457n	6·27830n	0·32424n	[illegible]	−∞	8·36389	8·36262n	0·30080	[illegible]	−∞	9·85012n	9·84885
Item ... y.	−1 35 44	222 28 33	1·57646n	−∞	[illegible]	7·94444	9·45136n	8·39928	8·82139	[illegible]	[illegible]	[illegible]	−∞	[illegible]	9·16713n	8·74390n	7·69148	0·37666n	0·26051n	−∞	[illegible]	8·31253n	0·29917	9·24675n	−∞	9·82949n	[illegible]
Item ... y.	−2 20 19	220 30 57	1·45209n	−∞	8·05373n	8·12260	9·44493n	8·64328	9·01765	[illegible]	[illegible]	[illegible]	−∞	[illegible]	9·17834n	[illegible]	8·16419	0·40694n	0·19507n	∞	8·42339	8·49166n	0·29533	9·49348n	−∞	[illegible]	[illegible]
Item ... y.	−3 21 49	219 9 46	1·47654n	−∞	8·19747n	8·28657	9·43552n	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−∞	[illegible]	9·18299n	9·05963n	8·37477	0·42359n	0·13988n	−∞	8·56883	8·65793n	0·29120	[illegible]	−∞	[illegible]	9·88950
Item ... y.	−5 1 40	218 9 25	1·38934n	∞	8·35776n	8·46219	9·41776n	[illegible]	[illegible]	[illegible]	[illegible]	54545	−∞	[illegible]	9·17961n	9·22957n	8·61611	0·43289n	0·09099n	−∞	8·73358	8·83831n	0·28684	9·67338n	−∞	9·79085n	9·89558
Item ... y.	−7 37 46	216 41 46	1·30878n	−∞	8·51327n	8·64100	9·37639n	8·85096	[illegible]	[illegible]	[illegible]	51299	−∞	9·03737	9·16510n	[illegible]	8·87629	[illegible]	[illegible]	−∞	8·89947	[illegible]	0·27865	9·75322n	−∞	9·77640n	9·90413
Item ... y.	−10 19 8	215 11 9	0·96942n	−∞	8·61237n	8·76425	9·31206n	8·86439	9·70651	9·14519	[illegible]	46974	−∞	8·98535	9·13713n	9·52117n	9·07393	0·44675n	9·89143n	−∞	[illegible]	9·16614n	0·26795	9·82017n	−∞	[illegible]	9·91238
Item ... y.	12 29 51	214 25 55	0·59988	∞	[illegible]	8·83324	9·24277n	[illegible]	[illegible]	9·15319	[illegible]	[illegible]	−∞	8·93755	9·10154n	9·59561n	9·18288	0·44448n	9·81794n	−∞	9·08762	9·25161n	0·26036	9·84763n	−∞	9·75237n	9·91636
Item ... y.	−14 20 42	213 38 6	1·12646	−∞	8·70233n	8·87933	9·16321n	8·78535	[illegible]	[illegible]	[illegible]	[illegible]	−∞	8·88525	[illegible]	9·64619n	9·26833	0·44168n	9·72648n	−∞	[illegible]	9·31446n	0·25216	[illegible]	−∞	9·74343n	[illegible]
Item ... y.	−16 27 25	210 26 34	1·38561	−∞	8·68992n	8·92975	[illegible]	8·76655	[illegible]	[illegible]	[illegible]	[illegible]	−∞	[illegible]	[illegible]	9·67644n	9·42227	0·44066n	8·80647n	−∞	9·15698	[illegible]	0·22420	9·96998n	−∞	[illegible]	[illegible]
Tacity, Point Venus ... y.	17 29 17	210 29 54	1·42732	∞	[illegible]	8·94243	8·94286n	8·68667	9·91373	[illegible]	[illegible]	26454	−∞	8·74662	[illegible]	9·70015n	9·44396	[illegible]	8·85249n	−∞	9·18331	9·41319n	0·22229	9·96610n	−∞	[illegible]	[illegible]
Pacific ... y.	−19 6 18	209 52 55	0·63849	∞	[illegible]	8·96023	[illegible]	8·52964	[illegible]	[illegible]	[illegible]	[illegible]	−∞	8·66533	[illegible]	9·72786n	9·49343	0·42808n	[illegible]	−∞	[illegible]	9·45299n	0·21292	9·97849n	−∞	[illegible]	[illegible]
Item ... y.	−23 34 0	209 48 47	1·36418	−∞	[illegible]	8·97313	8·42928	8·19723n	[illegible]	[illegible]	[illegible]	[illegible]	−∞	[illegible]	8·54203n	9·80095n	9·56890	0·40146n	[illegible]	−∞	[illegible]	[illegible]	[illegible]	[illegible]	−∞	[illegible]	[illegible]
Item ... y.	−27 19 17	210 2 10	1·49415	−∞	8·69954n	8·93746	9·01880	[illegible]	[illegible]	[illegible]	[illegible]	14884	−∞	[illegible]	[illegible]	9·84931n	[illegible]	[illegible]	[illegible]	−∞	[illegible]	[illegible]	[illegible]	[illegible]	−∞	[illegible]	9·93737
Item ... y.	−28 55 47	213 24 32	1·15381	−∞	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26036	−∞	[illegible]	8·42056	9·88057n	9·52124	[illegible]	[illegible]	−∞	[illegible]	[illegible]	0·20725	9·83892n	−∞	[illegible]	9·92156
Item ... y.	−30 32 49	213 6 55	1·11461	−∞	8·67416n	8·85974	[illegible]	8·90391n	[illegible]	[illegible]	[illegible]	[illegible]	−∞	8·50319n	[illegible]	9·90371n	9·54759	0·34153n	[illegible]	∞	9·44352	9·62910n	[illegible]	9·84152n	∞	[illegible]	[illegible]
Item ... y.	−33 53 27	216 42 58	1·17811n	∞	8·59343n	8·72079	[illegible]	[illegible]	[illegible]	9·59888	[illegible]	28238	−∞	8·82169n	[illegible]	[illegible]	9·42154	[illegible]	9·85254n	−∞	[illegible]	[illegible]	0·20175	[illegible]	−∞	[illegible]	9·90396
Item ... y.	−35 22 30	220 19 45	1·43696n	−∞	8·54414n	8·61527	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31266	−∞	[illegible]	[illegible]	9·96922n	[illegible]	[illegible]	[illegible]	−∞	[illegible]	[illegible]	0·20660	[illegible]	−∞	9·81102n	9·88215
Item ... y.	−37 38 58	218 18 11	1·55919n	−∞	8·32234n	8·42480	[illegible]	8·92659n	[illegible]	[illegible]	[illegible]	24853	−∞	9·03055n	9·13301	9·97355n	9·35034	0·23189n	9·89878n	−∞	9·57818	[illegible]	0·18764	[illegible]	−∞	9·79227n	9·89473
Item ... y.	−42 4 18	218 57 56	1·83479n	−∞	[illegible]	8·02651n	[illegible]	[illegible]	9·99468	[illegible]	[illegible]	17406	∞	[illegible]	9·28288	9·98801n	9·31809	[illegible]	9·87377n	−∞	9·62469	9·71684n	0·16190	9·59198n	−∞	9·79858n	[illegible]
Item ... y.	−44 45 18	223 49 44	1·93586n	−∞	8·51501	8·53276n	9·69957	8·31122n	[illegible]	9·84855	[illegible]	15460	−∞	9·31131n	[illegible]	9·99961n	8·61126	[illegible]	[illegible]	−∞	[illegible]	[illegible]	0·15199	8·76364n	−∞	[illegible]	9·85818
Item ... y.	45 4 59	228 38 4	1·96308n	∞	8·58818	8·53293n	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13447	−∞	9·35461n	9·29936	[illegible]	[illegible]	[illegible]	[illegible]	−∞	9·72548	[illegible]	0·14638	[illegible]	−∞	[illegible]	[illegible]
Item ... y.	−47 13 25	237 49 32	2·10072n	−∞	8·83554	8·63427n	9·68552	9·36696	[illegible]	[illegible]	[illegible]	89397	−∞	9·45748n	9·25621	9·95363n	9·63537n	9·19645n	[illegible]	−∞	[illegible]	9·59202n	0·08793	9·76937	−∞	[illegible]	[illegible]
Item ... y.	−48 30 36	244 11 51	2·07504n	−∞	8·95129	8·63566n	9·03785	9·53681	9·33250n	9·98347	[illegible]	42552	−∞	9·51206n	9·19643	[illegible]	9·78988n	[illegible]	[illegible]	−∞	9·82892	9·51329n	[illegible]	[illegible]	−∞	9·95439n	9·63876
Item ... y.	−51 2 36	252 38 48	2·20860n	∞	9·11639	8·61122n	9·51038	9·67889	9·75357n	[illegible]	[illegible]	54352n	−∞	[illegible]	[illegible]	9·74566n	[illegible]	[illegible]	[illegible]	∞	[illegible]	9·36537n	9·85489	0·01440	−∞	[illegible]	[illegible]
Item ... y.	−55 3 0	266 42 15	1·94498n	∞	9·29896	8·05826n	8·84243	[illegible]	[illegible]	9·14155	[illegible]	86461n	−∞	[illegible]	8·43229	9·03263n	9·06983n	[illegible]	[illegible]	∞	9·91291	[illegible]	[illegible]	0·05620	−∞	9·99928n	[illegible]
Item ... y.	−56 28 30	276 54 55	1·91829n	−∞	9·34334	8·42743	[illegible]	[illegible]	9·85334n	[illegible]	[illegible]	77590n	−∞	9·69138n	[illegible]	9·34267	9·95142n	[illegible]	[illegible]	−∞	9·91781	[illegible]	9·42169n	0·03044	−∞	9·99683n	[illegible]
Item ... y.	−56 5 8	284 56 50	0·94792n	−∞	9·31921	8·74545	9·48226n	9·72267	[illegible]	[illegible]	[illegible]	54143n	−∞	9·67469n	[illegible]	9·66442	[illegible]	[illegible]	[illegible]	−∞	[illegible]	[illegible]	[illegible]	9·98562	−∞	[illegible]	[illegible]
Item ... y.	−58 31 12	289 57 14	1·67052	−∞	9·37927	8·93024	9·59285n	9·67045	9·54443n	[illegible]	[illegible]	00306n	∞	9·69519n	9·25516n	9·75696	9·83456n	[illegible]	9·84973	∞	[illegible]	9·46394	[illegible]	9·90370	−∞	9·97311n	9·53308n
Item ... y.	−56 21 30	299 34 22	1·46300	−∞	9·28228	[illegible]	9·71881n	9·49508	8·23442n	9·88443n	[illegible]	50828	−∞	[illegible]	9·38625n	9·89866	9·67493n	[illegible]	9·96401	−∞	9·85978	[illegible]	9·97826n	[illegible]	−∞	9·93930n	[illegible]
Atlantic ... y.	−51 28 19	304 46 58	1·50840	∞	[illegible]	8·91305	9·73852n	[illegible]	9·35344	9·91557n	[illegible]	86396	−∞	[illegible]	9·37112n	[illegible]	9·53182n	[illegible]	05220	−∞	9·80788	[illegible]	[illegible]	9·63845	−∞	9·91451n	9·75623n
Item ... y.	47 10 42	306 46 24	1·68413	−∞	[illegible]	8·68157	[illegible]	9·18223	[illegible]	[illegible]	[illegible]	02310	−∞	[illegible]	[illegible]	9·98058	9·45089n	9·68244n	[illegible]	−∞	9·76902	9·64256	[illegible]	9·58551	−∞	[illegible]	[illegible]
Item ... y.	41 26 39	308 22 17	1·35927	−∞	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−∞	[illegible]	[illegible]	9·98492	9·35708n	9·85459n	[illegible]	−∞	9·71511	9·61372	[illegible]	9·53629	−∞	9·89433n	[illegible]
Item ... y.	−37 43 4	309 47 54	0·98815	−∞	[illegible]	[illegible]	[illegible]	8·82026	9·75102	[illegible]	[illegible]	26734	−∞	[illegible]	[illegible]	9·97861	9·74247n	[illegible]	[illegible]	−∞	[illegible]	9·59283	[illegible]	9·45588	−∞	9·88553n	[illegible]
Item ... y.	−34 24 27	311 26 26	1·27091	−∞	[illegible]	8·61126n	9·45829n	8·55479	9·81333	9·97909n	9·74228	33792	−∞	[illegible]	8·80744n	[illegible]	[illegible]	[illegible]	[illegible]	−∞	9·62696	9·57287	[illegible]	9·31064	−∞	[illegible]	9·82076n
Item ... y.	−28 55 46	314 9 52	0·74896	−∞	8·82941n	8·81674n	9·20254n	[illegible]	9·87559	9·91364n	9·19488	42768	−∞	8·38683n	8·37410n	9·92757	8·39256n	0·19099n	[illegible]	−∞	9·54033	9·52766	[illegible]	8·70796	−∞	[illegible]	[illegible]

Stations and observed elements.	Latitude. ° ′ ″	Long. East, Greenwich. ° ′ ″	Log. n	Log. coef. $\Delta g^{4,0}$.	Log. coef. $\Delta g^{4,1}$.	Log. coef. $\Delta h^{4,1}$.	Log. coef. $\Delta g^{4,2}$.	Log. coef. $\Delta h^{4,2}$.
Atlantic . . . . . y	26 22 0	315 46 7	0·95617	−∞	8·85533n	8·86697n	8·98852n	7·41708n
Item . . . . . y	−24 12 12	316 35 34	1·00860	−∞	8·86564n	8·88980n	8·66215n	7·40759n
Rio de Janeiro . . . . . y	22 53 54	316 55 3	1·17435	−∞	8·86700n	8·89660n	8·19584n	7·02964n
Pacific . . . . . z	9 19 3	235 49 9	1·63215	9·41070n	9·26843	9·43651	9·10887n	9·51038
Item . . . . . z	6 51 21	236 24 54	1·77605	9·29320n	9·31621	9·49403	9·01065n	9·38639
Item . . . . . z	5 12 0	236 2 37	1·73135	9·18119n	9·34607	9·51778	8·88344n	9·27514
Item . . . . . z	2 41 46	234 6 3	1·75259	8·90390n	9·39168	9·53185	8·52393n	9·00698
Item . . . . . z	1 9 28	233 0 34	1·82523	8·53899n	9·40978	9·53282	8·10505n	8·64698
Item . . . . . z	0 3 53	231 19 22	1·78831	7·28330	9·42785	9·52450	6·75261	7·40166n
Item . . . . . z	−0 2 37	229 18 54	1·85132	7·09342	9·44620	9·51186	6·40567	7·22448n
Item . . . . . z	−0 53 23	228 3 18	1·70766	8·41548	9·45613	9·50253	7·57112	8·54154n
Item . . . . . z	−1 49 45	226 40 35	1·54704	8·73697	9·46442	9·48984	7·62918	8·86134n
Item x	−1 52 14	225 5 1	1·78930	8·74672	9·47667	9·47794	6·33548	8·87175n
Item . . . . . z	1 35 44	222 28 33	1·75549	8·67853	9·49670	9·45845	7·74888n	8·80130n
Item . . . . . z	−2 20 10	220 30 57	1·59028	8·84275	9·50643	9·43816	8·16091n	8·96276n
Item . . . . . z	−3 21 49	219 9 46	1·39620	8·99838	9·50790	9·41880	8·43011n	9·11500n
Item . . . . . z	−5 1 40	218 9 25	1·04493	9·16729	9·49676	9·39203	8·66825n	9·28169n
Item . . . . . z	−7 37 46	216 41 46	1·26623	9·33506	9·41285	9·35492	8·92068n	9·44611n
Item . . . . . z	−10 19 8	215 11 9	1·25285n	9·44685	9·40185	9·25007	9·10676n	9·35453n
Item . . . . . z	−12 29 51	214 25 55	1·41128n	9·50862	9·32579	9·16180	9·20574n	9·61647n
Item . . . . . z	−14 20 42	213 38 6	0·37658	9·54720	9·23619	9·05919	9·27697n	9·65483n
Item . . . . . z	−16 27 25	210 26 34	0·70757n	9·57867	8·90992	8·86838	9·41448n	9·66870n
Taiti, Point Venus x	−17 29 17	210 29 54	9·55630	9·58861	8·97775	8·74786	9·42725n	9·68344n
Pacific . . . . . z	−19 6 18	209 52 55	1·69373n	9·59964	8·72558	8·48494	9·46127n	9·69570n
Item . . . . . z	−23 34 0	209 48 47	1·58715	9·59903	8·87178n	8·62995n	9·48439n	9·71644n
Item . . . . . z	−27 19 17	210 7 10	1·40071	9·55078	9·25244n	9·01452n	9·46711n	9·70756n
Item . . . . . z	−28 55 47	213 24 32	1·84979	9·52165	9·31969n	9·13897n	9·35359n	9·72192n
Item . . . . . z	−30 32 49	213 6 55	1·54469	9·47388	9·40144n	9·21586n	9·34433n	[illegible]
Item . . . . . z	−33 53 27	216 42 58	1·81177	9·33802	9·48812n	9·36076n	9·13836n	9·66491n
Item . . . . . z	−35 22 30	220 19 45	1·54851	9·24655	9·50000n	9·42893n	8·85985n	9·64307n
Item . . . . . z	−37 38 58	218 18 11	1·58805	9·03072	9·57149n	9·44903n	8·94874n	9·57195n
Item . . . . . z	−42 4 18	218 57 56	1·89025	8·60840n	9·58695n	9·49480n	8·70712n	9·37704n
Item . . . . . z	−44 45 18	223 40 44	1·85175	9·12797n	9·55761n	9·53086n	7·79144n	9·10979n
Item . . . . . z	−45 4 59	228 38 4	1·60927	9·16373n	9·51893n	9·57418n	8·24813	9·14238n
Item . . . . . z	−47 13 25	237 49 32	1·71875	9·34197n	9·41512n	9·61639n	8·45025	8·76881n
Item . . . . . z	−48 30 36	244 11 51	1·75565	9·42014n	9·31668n	9·63231n	8·10375	8·20479n
Item . . . . . z	−51 2 36	252 38 48	1·93847	9·53714n	9·11920n	9·62437n	8·72825n	8·56874
Item . . . . . z	−55 3 0	266 42 15	2·01486	9·65979n	8·31147n	9·55225n	9·27259n	8·33539
Item . . . . . z	−56 28 30	276 54 55	1·82295	9·69075n	8·58597	9·50218n	9·34426n	8·73551n
Item . . . . . z	−56 5 8	284 56 50	1·89265	9·68281n	8·93086	9·50447n	9·27481n	9·03440n
Item . . . . . z	−58 31 17	289 57 14	1·82911	9·72606n	8·94953	9·38956n	9·32841n	9·25081n
Item . . . . . z	−56 21 30	299 34 22	1·85003	9·68845n	9·20284	9·44889n	9·06114n	9·28487n
Atlantic x	−51 28 19	304 46 58	1·65331	9·55330n	9·39356	9·55184n	8·44095n	8·80973n
Item x	−47 10 47	306 46 24	1·40552	9·33878n	9·46629	9·59275n	8·27645	8·80614
Item x	−41 26 39	308 22 17	1·88013	8·20198n	9·48624	9·58763n	8·78301	9·41085
Item x	−37 43 4	309 47 54	1·66671	9·02178	9·46402	9·54331n	8·83832	9·57446
Item . . . . . z	−34 24 27	311 26 26	1·76641	9·30903	9·41759	9·47168n	8·76539	9·66889
Item . . . . . z	−28 55 46	314 9 52	1·75626	9·51786	9·24941	9·26208n	8·22181	9·75682
Item . . . . . z	26 22 0	315 46 7	1·84776	9·56609	9·10215	9·00051n	8·20334n	9·77478
Item . . . . . z	24 12 12	316 35 34	1·99550	9·59067	8·88955	8·86539n	8·52541n	9·77987
Rio de Janeiro . . . . . z	22 53 54	316 55 3	0·07188	9·59924	8·66806	8·63846n	8·61255n	9·77875

Stations and observed elements.	Log. coef. $\Delta g^{4,3}$.	Log. coef. $\Delta h^{4,3}$.	Log. coef. $\Delta g^{4,4}$.	Log. coef. $\Delta h^{4,4}$.	Log. coef. $\Delta g^{3,0}$.	Log. coef. $\Delta g^{3,1}$.	Log. coef. $\Delta h^{3,1}$.	Log. coef. $\Delta g^{3,2}$.	Log. coef. $\Delta h^{3,2}$.
Atlantic y	9·89546	9·86048n	9·18811n	0·45831	−∞	7·28207	7·29370	9·90065	8·32921
Item y	9·89279	9·82003n	9·52731n	0·47949	−∞	8·34113	8·36529	9·87316	8·61870
Rio de Janeiro y	9·88549	9·79615n	9·62795n	0·49110	−∞	8·52012	8·54972	9·85444	8·68824
Pacific z	9·92988	9·27706n	9·65013	9·63005	9·71138n	9·28542n	9·45350n	9·52542n	9·92693
Item z	9·96059	9·23922n	9·51403	9·52404	9·74294n	9·15364n	9·33146n	9·56674n	9·94248
Item z	9·97253	9·29514n	9·40212	9·40476	9·75816n	9·04189n	9·21360n	9·56258n	9·95428
Item z	9·97413	9·47850n	9·17815	9·04642	9·77285n	8·78886n	8·92203n	9·49128n	9·97433
Item z	9·96934	9·55284n	8·83557	8·83203	9·77717n	8·42709n	8·55013n	9·44025n	9·98288
Item z	9·95355	9·64231n	7·61159n	7·28614n	9·77815n	7·19155	7·28820	9·34032n	9·98934
Item z	9·92816	9·72488n	7·45246n	6·94480n	9·77815n	6·82701	6·89267	9·17624n	9·99505
Item z	8·90834	9·76692n	8·78318n	8·11879n	9·77758n	8·35858	8·40498	9·02674n	9·99716
Item z	9·88223	9·80558n	9·10247n	8·17284n	9·77571n	8·68227	8·70769	8·76554n	9·99770
Item x	9·84004	9·84555n	9·11313n	7·87980n	9·77359n	8·70441	8·70568	7·46210n	9·99837
Item z	9·78604	9·89819n	[illegible]	8·29009	9·77028n	8·65449	8·61618	8·94470	9·99712
Item z	9·71502	9·92089n	[illegible]	8·70019	9·77415n	8·83309	8·76482	9·19027	9·99212
Item z	9·65674	[illegible]	9·33114n	8·96626	9·76986n	8·99831	8·96921	9·30080	9·98566
Item z	9·60332	9·94222n	9·48818n	9·70231	9·75947n	9·17618	9·07145	9·30223	9·97569
Item z	9·47693	9·93327n	[illegible]	9·45211	9·73422n	9·35906	9·23133	9·42861	9·95404
Item z	9·35449	9·90981n	[illegible]	9·63584	9·49479n	9·48968	9·33730	9·47507	9·92284
Item z	9·25074	9·87728n	[illegible]	9·73385	9·65188n	9·56538	9·40144	9·48086	9·89359
Item z	9·12701	9·84221n	[illegible]	[illegible]	9·66518n	9·61892	9·44192	9·48494	9·86280
Item z	8·16119	9·79538n	[illegible]	9·92928	9·53718n	9·67989	9·44906	9·54934	9·80355
Taiti, Point Venus x	8·18071	9·76409n	9·74210n	9·94662	9·49674n	9·69854	9·46866	9·52782	9·78401
Pacific z	7·51477n	9·72276n	[illegible]	9·98278	9·42044n	9·72684	9·48620	9·50910	9·74353
Item z	7·47139n	[illegible]	[illegible]	0·03121	9·04299n	9·77559	9·53376	9·38239	9·61444
Item z	0·36272	[illegible]	[illegible]	[illegible]	8·35391	9·79432	9·55660	9·11247	9·45232
Item z	7·99696	[illegible]	[illegible]	9·97230	8·91890	9·78151	9·60079	9·02209	9·39162
Item z	7·80241n	8·58608	[illegible]	9·98137	9·17797	9·78313	9·59755	8·89281	9·24893
Item z	8·76232n	9·19737	[illegible]	[illegible]	9·44134	9·75314	9·62578	8·20141	8·72796
Item z	9·06666n	[illegible]	[illegible]	9·60530	9·51931	9·72197	9·65084	6·85815n	7·64197n
Item z	9·31395n	[illegible]	[illegible]	9·73760	9·61399	9·71436	9·61190	8·33993n	8·96314n
Item z	9·29719n	9·59229	[illegible]	9·65160	9·74381	9·64783	9·55568	8·73116n	9·40108n
Item z	9·51631n	9·56970	[illegible]	8·91562	9·79933	9·55879	9·54104	8·15840n	9·53865n
Item z	9·61834n	9·44888	9·90459n	9·39850n	9·80524	9·51258	9·56783	8·65390	9·54815n
Item z	9·72370n	8·78193	9·75007n	[illegible]	9·83897	9·35822	9·55949	9·25812	9·57668n
Item z	9·72678n	9·07585n	[illegible]	9·91348n	9·85597	9·22555	9·54208	9·44898	9·55002n
Item z	9·04575n	9·53752n	9·43429	9·85935n	9·88271	8·95174	9·45701	9·62405	9·40454n
Item z	8·97800n	9·73680n	[illegible]	9·14790n	9·90896	7·93815	9·17893	9·76185	8·82465n
Item z	9·28401	[illegible]	9·66088	9·41630	9·91385	8·05205	8·96886	9·76480	9·15605
Item z	9·58470	9·58710n	[illegible]	9·69820	9·91275	8·45719n	9·03095	9·71238	9·47197
Item z	9·65548	9·41732n	8·95392	9·67954	9·91704	7·72018n	8·16021	9·67526	9·59766
Item z	9·73545	8·08546n	9·42808n	9·69772	9·91356	8·69542n	8·94150	9·48664	9·71037
Atlantic x	9·73584	9·14371	9·75733n	9·69450	9·88643	9·21074n	9·36902	9·25961	9·68839
Item x	9·69816	9·26673	9·88518n	9·69764	9·83831	9·41052n	9·53698	9·07259	9·00228
Item x	9·58300	9·25394	9·99938n	9·69707	9·72873	9·56099n	9·66238	8·73264	9·36048
Item x	9·43295	9·18373	[illegible]	9·63371	9·61654	9·62513n	9·70442	8·24408	8·98022
Item z	9·19272	9·02696	[illegible]	9·49439	9·47024	9·66702n	9·72111	7·63358n	8·53708n
Item z	8·55891n	8·52086n	0·11228n	8·87868	8·95034	9·70320n	9·71586	7·88128n	9·41629n
Item z	9·06032n	9·09530n	[illegible]	8·83570n	7·87189n	9·70909n	9·69745	7·99168	9·56312n
Item z	9·24560n	9·31836n	[illegible]	9·14007n	8·94122n	9·70336n	9·67920	8·40008	9·65464n
Rio de Janeiro z	9·32491n	9·41425n	[illegible]	9·21801n	9·12812n	9·69583n	9·66623	8·53418	9·70038n

Stations and observed elements.	Log. coef. $\Delta g^{3,3}$.	Log. coef. $\Delta h^{3,3}$.	Log. coef. $\Delta g^{2,0}$.	Log. coef. $\Delta g^{2,1}$.	Log. coef. $\Delta h^{2,1}$.	Log. coef. $\Delta g^{2,2}$.	Log. coef. $\Delta h^{2,2}$.	Log. coef. $\Delta g^{1,0}$.	Log. coef. $\Delta g^{1,1}$.	Log. coef. $\Delta h^{1,1}$.
Atlantic y	0·24797n	0·21299	−∞	9·49108	9·50272	0·25316n	8·08172n	−∞	9·84359n	9·85523n
Item y	0·28003n	0·20727	−∞	9·44983	9·47399	0·26640n	9·00584n	−∞	9·83707n	9·86173n
Rio de Janeiro y	0·29543n	0·20609	−∞	9·42424	9·45384	[illegible]	9·09818n	∞	9·83418n	9·86378n
Pacific z	9·66435n	9·01153	9·50451	9·72619n	9·89427n	9·07126	9·47277n	9·99423	8·95882	9·12690
Item z	9·54108n	8·81871	9·37480	[illegible]	9·90812n	8·96363	9·33937n	9·99089	8·81974	8·99756
Item z	9·42043n	8·74404	9·25652	9·73980n	9·91160n	8·83172	9·22342n	9·99821	8·70436	[illegible]
Item z	9·12752n	8·63143	8·97296	9·76641n	9·90658n	8·40762	8·95067n	9·99952	8·44005	8·55092
Item z	8·75173n	8·33633	8·60619	9·77900n	9·90240n	8·04730	8·58920n	9·99991	8·08491	8·20795
Item z	7·43387	7·17773n	7·35433n	9·79583n	9·89248n	6·90465n	7·34367	0·00000	6·84913n	6·91578n
Item z	7·27569	7·04241n	7·17144n	9·81418n	9·87984n	6·31768n	7·16449	0·00000	6·68459n	6·75025n
Item z	8·57711	8·43574n	8·49221n	9·82484n	9·87124n	7·51331n	8·48373	9·99995	8·04678n	8·06268n
Item z	8·86518	8·78853n	8·80426n	9·83552n	9·86096n	7·57196n	8·80412	9·99978	8·34045n	8·36387n
Item x	8·84180	8·83801n	8·81456n	9·84793n	9·84920n	6·77330n	8·81457	9·99977	8·36262n	8·36389n
Item z	8·70524	8·82139n	8·74559n	9·86713n	9·82882n	7·09148	8·74390	9·99983	8·31253n	8·27422n
Item z	8·80578	9·01765n	8·91138n	9·87950n	9·81123n	8·10419	8·90604	9·99964	8·49166n	8·42339n
Item z	8·90831	9·19202n	9·06871n	9·88650n	9·79740n	8·37417	9·05963	9·99925	8·65793n	8·56883n
Item z	9·03072	9·37562n	9·24208n	9·88885n	9·79182n	8·61611	9·22957	9·99832	8·83831n	8·73358n
Item z	9·10886	9·56520n	9·42023n	9·88836n	9·76083n	8·87629	9·40172	9·99613	9·02720n	8·89947n
Item z	9·14519	9·70651n	9·54771n	9·88349n	9·73171n	9·07393	9·53171	9·99292	9·16614n	9·01436n
Item z	9·13319	9·77973n	9·62586n	9·87366n	9·70967n	9·18288	9·59561	9·98958	9·25161n	9·08762n
Item z	9·12051	9·83571n	9·61830n	9·86354n	9·68654n	9·16833	9·64019	9·98624	9·31446n	9·13740n
Item z	8·95871	9·89209n	9·73510n	9·85958n	9·62875n	9·13222	9·67644	9·98183	9·38781n	9·15698n
Taiti, Point Venus x	8·33035	9·91373n	9·75834n	9·84882n	9·61894n	9·44396	9·70015	9·97945	9·41319n	9·18331n
Pacific z	7·72703n	9·94302n	9·79137n	9·83333n	9·59269n	9·49393	9·72786	9·97540	9·45299n	9·21235n
Item z	7·99334n	0·00332n	9·86507n	9·77104n	9·52921n	9·36890	9·80095	9·96218	9·51020n	9·29837n
Item z	7·30486	0·03618n	9·91146n	9·69979n	9·46187n	9·06946	9·84931	9·94863	9·50917n	9·36125n
Item z	9·29433	0·03805n	9·92613n	9·65153n	9·47081n	9·32124	9·88957	9·94278	9·60388n	9·42316n
Item z	9·26394	0·04761n	9·94221n	9·60733n	9·42175n	9·41759	9·90371	9·93511	9·62910n	9·44352n
Item z	9·50888	0·03429n	9·96650n	9·48158n	9·35422n	[illegible]	9·94809	9·91913	9·65030n	9·55794n
Item z	9·77416	9·99560n	9·97502n	9·40026n	9·32913n	9·18540	9·96922	9·91131	9·64477n	9·57364n
Item z	9·68469	0·01780n	9·98553n	9·29918n	9·10672n	[illegible]	9·97355	9·89869	9·68064n	9·57818n
Item z	9·69988	9·99468n	9·99772n	8·89950n	[illegible]	[illegible]	9·98801	[illegible]	9·71684n	9·62469n
Item z	9·84555	9·90194n	9·99998n	7·79079n	[illegible]	8·61126	9·99961	9·85133	9·70580n	9·68805n
Item z	9·94303	9·73357n	0·00000n	7·28384	[illegible]	[illegible]	9·99650	9·84885	9·67023n	9·72548n
Item z	0·00792	9·66215n	9·99869n	8·61585	8·81712	9·63537n	9·95361	9·83196	9·59207n	9·79329n
Item z	9·98343	9·33250n	9·99674n	8·72588	[illegible]	[illegible]	[illegible]	9·82118	9·51329n	9·82890n
Item z	9·86170	9·75357	9·99026n	[illegible]	[illegible]	[illegible]	9·71566	9·79846	9·36537n	[illegible]
Item z	9·13155	9·90035	9·97271n	8·29463	9·53541	[illegible]	9·63263	[illegible]	8·67213n	9·91291n
Item z	9·43172n	9·85334	9·96419n	8·67160n	9·58781	[illegible]	9·34267n	9·74218	9·00160	[illegible]
Item z	9·73761n	9·74001	9·96664n	8·98827n	9·56183	[illegible]	9·66442n	9·74660	[illegible]	[illegible]
Item z	[illegible]	9·54443	9·94973n	9·19072n	9·63075	9·83456n	9·75696n	9·71784	9·46394	[illegible]
Item z	9·88443n	8·23442	9·96493n	9·28009n	9·52617	9·07493n	9·89866n	9·74350	9·61370	9·85978n
Atlantic x	9·94557n	9·35344n	9·98882n	9·10641n	9·26475	9·53182n	9·96060n	9·79442	9·64960	[illegible]
Item x	9·97925n	9·54782n	9·99874n	8·65779n	8·78425	9·45089n	9·98058n	9·83733	9·64156	[illegible]
Item x	0·00445n	9·67538n	9·99665n	8·88567	8·98706n	9·35708n	9·98492n	9·87483	9·61372	9·71511n
Item x	0·00023n	9·75102n	9·98581n	9·20673	9·28602n	9·24247n	9·97861n	9·89819	9·59083	9·67212n
Item z	9·97009n	9·81333n	9·96961n	9·37872	9·43781n	9·06275n	9·96625n	9·91647	9·57287	9·62696n
Item z	9·91364n	9·87559n	9·92775n	9·56898	9·58165n	8·39156n	9·92757n	9·94212	9·52766	9·54033n
Item z	9·86048n	9·89546n	9·90081n	9·63738	9·62574n	8·32921	9·90065n	9·95229	9·50272	9·49108n
Item z	9·82003n	9·89279n	9·87383n	9·68329	9·65913n	8·61870	9·87316n	9·96004	9·47399	9·44983n
Rio de Janeiro z	9·79615n	9·88549n	9·85545n	9·70715	9·67755n	8·68824	9·85444n	9·96436	9·45384	9·42424n

FINAL EQUATIONS FOR THE CORRECTIONS OF THE GAUSSIAN CONSTANTS, RESULTING FROM 448 OBSERVED ELEMENTS.

	$\Delta g^{4,0}$.	$\Delta g^{4,1}$.	$\Delta h^{4,1}$.	$\Delta g^{4,2}$.	$\Delta h^{4,2}$.	$\Delta g^{4,3}$.	$\Delta h^{4,3}$.	$\Delta g^{4,4}$.	$\Delta h^{4,4}$.	$\Delta g^{3,0}$.	$\Delta g^{3,1}$.	$\Delta h^{3,1}$.	$\Delta g^{3,2}$.	$\Delta h^{3,2}$.	$\Delta g^{3,3}$.	$\Delta h^{3,3}$.	$\Delta g^{2,0}$.	$\Delta g^{2,1}$.	$\Delta h^{2,1}$.	$\Delta g^{2,2}$.	$\Delta h^{2,2}$.	$\Delta g^{1,0}$.	$\Delta g^{1,1}$.	$\Delta h^{1,1}$.
[illegible]	43·2936	+ 0·0569	+ 6·5297	+ 9·4463	−17·1018	+ 0·1205	− 4·7423	− 6·6810	− 4·3324	+ 47·6537	+ 6·3537	+ 4·5429	+ 12·9665	− 18·0123	+ 23·0173	− 9·7950	+ 31·7854	+ 0·3927	− 29·6327	+ 16·7052	− 4·9568	+ 16·8750	− 8·0055	− 41·4373
[illegible]	+ 0·0569	+ 26·0010	+ 5·9852	− 2·8367	+ 21·1459	− 0·6620	− 7·1183	− 4·7698	− 22·1129	− 4·1616	+ 33·0448	+ 6·0221	− 2·4614	+ 28·5780	+ 7·5061	+ 8·3148	− 2·6842	+ 33·0037	− 0·6801	− 10·7335	+ 15·4065	+ 1·1560	+ 28·2681	− 0·5668
[illegible]	+ 6·5297	+ 5·9852	+ 41·5122	− 23·1080	1·5990	+ 6·8106	− 9·5621	− 1·4102	− 25·3345	+ 31·6443	+ 5·9659	+ 50·0330	− 20·3968	+ 6·8467	+ 13·8517	+ 6·7114	+ 76·9584	− 0·7501	+ 56·7256	− 30·6511	+ 1·8943	+ 88·8198	− 0·6309	+ 26·7432
[illegible]	+ 9·4463	− 2·8367	− 23·1080	+ 58·6219	− 2·6833	− 5·9382	+ 37·2996	− 11·1845	− 12·6844	− 1·6537	− 12·0551	− 30·9667	+ 63·6386	− 5·5766	+ 3·6460	+ 39·3228	− 28·9717	5·5482	− 64·9665	+ 76·0668	+ 2·6901	− 31·2613	− 10·0767	− 51·3403
[illegible]	− 17·1018	+ 21·1459	− 1·5990	− 2·6833	+ 86·5590	− 44·0285	− 4·3987	+ 34·7606	− 6·7681	− 4·4458	+ 24·4101	− 12·4892	− 5·1535	+ 79·0977	− 59·3961	+ 17·6946	+ 21·9601	+ 52·9228	− 9·9218	+ 3·2201	+ 79·6324	+ 27·9431	+ 53·1943	+ 10·8139
[illegible]	+ 0·1205	− 0·6620	+ 6·8106	− 5·9382	− 44·0285	+ 135·8839	9·5115	16·1364	+ 7·1569	− 11·5816	− 12·6873	− 11·2762	− 31·8214	− 0·9267	+ 92·9191	− 15·1422	4·1063	− 56·3578	− 45·0098	− 14·7873	55·1526	+ 17·7184	− 42·9833	− 42·1670
[illegible]	− 4·7423	− 7·1183	− 9·5621	+ 37·2996	− 4·3987	− 9·5115	+ 123·5113	− 46·4572	+ 27·9282	+ 15·9710	+ 6·1787	− 3·9475	+ 24·4829	− 35·8777	− 15·1395	+ 46·8859	− 11·8998	+ 40·4625	+ 3·9994	+ 64·7109	+ 13·8956	− 25·5339	+ 2·1524	− 29·4044
[illegible]	− 6·6810	− 4·7698	− 1·4102	− 11·1845	+ 34·7606	− 16·1364	− 46·4572	+ 703·6124	+ 15·4086	+ 6·1490	− 48·3546	− 46·4950	− 20·8428	− 31·5475	− 360·0466	+ 343·4613	+ 105·0530	+ 1·1168	− 25·2327	− 16·2396	− 406·8365	+ 16·7865	+ 168·5621	+ 188·8841
[illegible]	− 4·3324	− 22·1129	− 25·3345	− 12·6844	− 6·7681	+ 7·1569	+ 27·9282	+ 15·4086	+ 624·2136	+ 45·0562	+ 7·0517	− 24·0498	+ 2·7822	− 68·4793	− 294·8165	− 305·3294	+ 14·6415	+ 37·5764	+ 15·2554	+ 301·8922	− 53·2868	− 50·1869	− 81·6733	+ 109·9278
[illegible]	+ 47·6537	− 4·1616	+ 31·6443	− 1·6537	− 4·4458	− 11·5816	+ 15·9710	+ 6·1490	+ 45·0562	+ 115·3676	− 1·4187	+ 34·9162	+ 4·7842	− 33·8166	− 20·7531	− 28·6215	+ 10·6463	+ 8·8891	+ 26·3086	+ 31·0754	− 26·6770	+ 105·4005	− 8·0638	− 22·5565
986·53	+ 6·3537	+ 33·0448	+ 5·9659	− 12·0551	+ 24·4101	− 12·6873	+ 6·1787	− 48·3546	+ 7·0517	− 1·4187	+ 72·7361	+ 16·7312	− 6·6373	+ 53·7324	+ 2·0616	− 23·6572	− 19·7493	+ 75·7643	+ 14·1546	− 0·4407	+ 68·4333	− 15·7185	+ 58·9792	− 7·9925
[illegible]	+ 4·5429	+ 6·0221	+ 50·0330	− 30·9667	− 12·4892	− 11·2762	− 3·9475	− 46·4950	− 24·0498	+ 34·9162	+ 16·7312	+ 114·0868	− 57·7638	− 8·4023	+ 32·3790	− 25·4407	+ 68·0117	+ 14·4451	+ 105·3837	− 4·9079	+ 29·4345	+ 146·9961	− 7·0706	+ 93·5519
981·33	+ 12·9665	− 2·4614	− 20·3968	+ 63·6386	− 5·1535	− 31·8214	+ 24·4829	− 20·8428	+ 2·7822	+ 4·7842	− 6·6373	− 57·7638	+ 133·9206	1·9172	− 16·2543	+ 66·0799	− 5·1180	− 21·9188	− 56·4317	+ 105·5147	− 21·9718	− 56·6382	+ 6·9960	− 78·2292
− 1194·8	− 18·0123	+ 28·5780	+ 6·8467	− 5·5766	+ 79·0977	− 0·9267	− 35·8777	− 31·5475	− 68·4793	− 33·8166	+ 53·7324	− 8·4023	1·9172	+ 197·4945	− 55·5503	+ 16·0437	+ 1·4217	+ 32·3829	− 31·8825	− 21·5547	+ 120·7643	+ 47·3611	+ 99·1969	− 15·1265
− 6636·32	+ 23·0173	+ 7·5061	+ 13·8517	+ 3·6460	− 59·3961	+ 92·9191	− 15·1395	− 360·0466	− 294·8165	− 20·7531	+ 2·0616	+ 32·3790	16·2543	− 55·5503	+ 533·3026	− 53·5702	− 69·4629	− 39·2236	− 41·3230	− 184·4784	+ 212·0845	+ 22·0333	− 118·7202	− 203·4818
[illegible]	− 9·7950	+ 8·3148	+ 6·7114	+ 39·3228	+ 17·6946	− 15·1422	+ 46·8859	+ 343·4613	− 305·3294	− 28·6215	− 23·6572	25·4407	+ 66·0799	+ 16·0437	53·5702	+ 495·2567	+ 56·5604	− 5·4168	− 34·7658	− 104·9068	− 238·9996	+ 28·0964	+ 194·3564	+ 40·2317
[illegible]	+ 31·7854	− 2·6842	+ 76·9584	− 28·9717	+ 21·9601	− 4·1063	− 11·8998	+ 105·0530	+ 14·6415	+ 10·6463	− 19·7493	+ 68·0117	− 5·1180	+ 1·4217	− 69·4629	+ 56·5604	+ 280·5308	− 16·2283	+ 89·9112	− 6·9153	− 89·5797	+ 258·0640	+ 27·5005	+ 54·9033
+ 1559·28	+ 0·3927	+ 33·0037	0·7501	− 5·0482	+ 52·9228	− 56·3578	+ 40·4625	+ 1·1168	+ 37·5764	+ 8·8891	+ 75·7643	+ 14·4451	− 21·9188	+ 32·3829	− 39·2236	− 5·4168	− 16·2283	+ 151·2020	+ 28·8920	+ 6·8854	+ 102·3798	− 33·5843	+ 99·5847	+ 19·1071
+ 3126·44	− 29·6327	− 0·6801	+ 56·7256	− 64·9665	− 9·9218	− 45·0098	+ 3·9994	− 25·2327	+ 15·2554	+ 26·3086	+ 14·1546	+ 105·3837	− 56·4137	− 31·8825	− 41·3230	− 34·7658	+ 89·9112	+ 28·8920	+ 221·0423	− 78·6212	14·3604	+ 90·3028	+ 18·3355	+ 147·5975
+ 1874·02	+ 16·7052	− 10·7335	− 30·6511	+ 76·0668	+ 3·2201	− 14·7873	+ 64·7109	− 16·2396	+ 301·8922	+ 31·0754	− 0·4407	− 4·9079	+ 105·5147	− 21·5547	− 184·4784	101·9068	− 6·9153	+ 6·8854	− 78·6212	+ 314·5914	− 8·6938	− 36·8656	− 73·4149	− 12·3468
− 1874·02	− 4·9568	+ 15·4065	+ 1·8943	+ 2·6901	+ 79·6324	55·1526	+ 13·8956	− 406·8365	− 53·2868	− 26·6770	+ 68·4333	+ 29·4345	21·9718	+ 120·7643	+ 212·0845	− 238·9996	− 89·5797	+ 102·3798	− 14·8694	− 8·6938	+ 486·0010	+ 8·6108	67·1409	− 143·3315
387·48	+ 16·8750	+ 1·1066	+ 88·8198	− 31·2613	+ 27·9431	+ 17·7184	− 25·5339	+ 16·7865	− 50·1869	− 105·4005	− 15·7185	+ 146·9961	− 56·6382	+ 47·3611	+ 22·0333	+ 28·0964	+ 258·0640	− 33·5843	+ 90·3028	− 36·8659	+ 8·6108	+ 411·1027	− 8·8230	+ 114·9380
+ 1969·71	− 8·0055	+ 28·2681	0·6309	− 10·0767	+ 53·1943	− 42·9833	+ 2·1524	+ 168·5621	− 81·6733	+ 8·0638	+ 58·9792	− 7·0706	+ 6·9960	+ 99·1969	118·7202	+ 194·3564	+ 27·5005	+ 99·5847	+ 18·3355	− 73·4149	− 67·1409	− 8·8220	+ 239·7200	+ 65·1440
[illegible]	− 41·4373	− 0·5668	+ 26·7432	− 51·3403	+ 10·8139	− 42·1670	− 29·4044	+ 188·8841	+ 109·9278	− 22·5505	− 7·9925	+ 93·5519	78·2292	− 15·1265	− 203·4818	+ 40·2317	+ 54·9033	+ 19·1071	+ 147·5975	− 12·3468	− 143·3315	+ 114·9380	+ 65·1440	+ 299·7100

$\Sigma(nn) = 621724{\cdot}8$; or *mean value* of $n = \pm 37{\cdot}3$ for the elements Nos. 1–448. (11)

Stations and observed elements	Latitude.	Long. East Greenwich.	Log. n.	Log. coef. $\Delta g^{4,0}$.	Log. coef. $\Delta g^{4,1}$.	Log. coef. $\Delta h^{4,1}$.	Log. coef. $\Delta g^{4,2}$.	Log. coef. $\Delta h^{4,2}$.	Log. coef. $\Delta g^{4,3}$.	Log. coef. $\Delta h^{4,3}$.	Log. coef. $\Delta g^{4,4}$.	Log. coef. $\Delta h^{4,4}$.
Atlantic Ocean ... z.	−34 18 1[illegible]	319 37 25	1·2330[illegible]n	9·18738n	9·56854	9·49815n	8·24822	9·03657n	9·90598	0·12497	0·51471n	0·39060n
Item ... z.	−24 23 45	323 50 35	1·29003n	9·21139n	9·59157	9·45533n	8·57517	9·07152n	9·69495	0·17118	0·44559n	0·29681n
Item ... z.	−20 55 43	324 43 14	1·50037n	8·56703n	9·61337	9·46337n	8·34477n	8·79783	9·60022	0·14595	0·47703n	0·37560n
Item ... z.	−19 31 53	324 53 38	1·46135n	8·07918	9·61097	9·45790n	8·66072n	9·11368	9·56780	0·13021	0·48293n	0·40073n
Item ... z.	−16 54 18	326 4 29	1·06032n	9·00817	9·59888	9·42663n	9·00266n	9·39298	9·41477	0·09577	0·47698n	0·40636n
Item ... z.	−15 4 45	326 13 [illegible]	0·73799n	9·20700	9·57851	9·39571n	9·14420n	9·50724	9·30163	0·06213	0·47392n	[illegible]129n
Item ... z.	−18 18 5[illegible]	327 15 35	0·44091n	9·33345	9·54876	9·35695n	9·24698n	9·58788	9·18083	0·02109	0·46814n	0·52969n
Item ... z.	−9 41 [illegible]8	328 8 9	0·72263	9·49269	9·45045	9·21395n	9·39130n	9·69791	9·08102	9·90115	0·43830n	0·57373n
Item ... z.	−5 19 12	329 4 5	·78888	9·59389	9·22088	8·99848n	9·49673n	9·76837	8·34800	9·66000	0·42790n	0·61146n
Item ... z.	−3 51 14	329 10 2	0·86618	9·61204	9·08669	8·86246n	9·51450n	9·78248	8·15923	9·52308	0·43168n	0·61714n
Item ... z.	−1 52 59	329 23 54	0·05690	9·62726	8·78097	8·55588n	9·53291n	9·79280	7·71323	9·21474	[illegible]	0·62453n
Item ... z.	+0 25 45	329 35 31	0·66181	9·63175	8·14120n	7·90975	9·51175n	9·79473	6·90515n	8·57328n	0·41800n	0·029[illegible]n
Item ... z.	+2 30 18	329 21 25	0·18469	9·62361	8·90392n	8·07655	9·52883n	9·79022	7·86050n	9·33803n	0·42850n	0·63011n
Item ... z.	+5 52 10	331 10 44	1·34792	9·58461	9·27030n	9·01082	9·54183n	9·74301	8·40213	9·70010n	[illegible]	0·64612n
Item ... z.	+10 21 5	333 3 12	1·54432	9·47041	9·49447n	9·20064	9·19878n	9·63582	9·13439	9·60635n	0·15520n	0·64922n
Item ... z.	+13 35 15	331 6 17	1·62045	9·31586	9·57213n	9·31403	9·34350n	9·54423	8·79462	0·23420n	0·28400n	0·64790n
Item ... z.	+16 16 53	328 52 7	1·62180	9·08849	9·60538n	9·38641	9·13921n	9·41836	8·86583n	0·09260n	0·23510n	0·54375n
Item ... z.	+20 3 15	325 37 46	1·75251	7·79588n	9·61640n	9·45143	8·60065n	9·71665	9·51844n	0·14120n	[illegible]	0·42015n
Item ... z.	+23 59 44	322 51 5	1·76738	9·15670n	9·59087n	9·47012	8·41595	8·95640n	9·75290n	0·15938n	[illegible]	0·25933n
Item ... z.	+27 14 46	321 35 27	1·76960	9·39742n	9·54329n	9·44247	8·27820	9·40839n	9·83602n	0·16287n	[illegible]	0·14229n
Item ... z.	+30 24 46	319 55 8	1·81043	9·53301n	9·45926n	9·38432	8·85740	9·61830n	9·91237n	0·14680n	[illegible]	0·06915n
Item ... z.	+33 19 42	318 43 1	1·90488	9·61236n	9·33944n	9·28294	8·85624	9·74073n	9·90060n	0·12412n	[illegible]	9·90620n
Item ... z.	+34 44 35	318 18 37	1·87887	9·63939n	9·25890n	9·20861	8·83003	9·78530n	9·95827n	0·11191n	[illegible]	[illegible]
Item ... z.	+36 50 47	32[illegible] 32 37	1·76223	9·66848n	9·10571n	9·02114	9·12536	9·84321n	9·86350n	0·13090n	[illegible]	[illegible]88366n
Item ... z.	+39 16 53	324 2 2	1·83059	9·68674n	8·74015n	8·60087	9·3796[illegible]	9·86613n	9·65432n	0·14520n	0·10121n	[illegible]2165n
Item ... z.	+42 46 8	328 55 37	1·73632	9·08520n	8·84164	8·62167n	9·06274	9·87976n	8·87743n	0·12724	9·91810n	[illegible]9640n
Item ... z.	+46 46 18	335 41 36	1·85558	9·64098n	9·36691	9·02171n	9·77986	9·83473n	9·55621	0·04877n	9·13115n	[illegible]3863n
Item ... y.	−24 18 17	319 37 25	0·01703	−∞	8·83948n	8·90987n	8·67894n	7·80050n	9·94343	9·74440	0·98240	[illegible]43811
Item ... y.	−24 33 45	323 50 35	0·59439n	−∞	8·79755n	8·97379n	8·71477n	8·21840n	[illegible]	9·51429n	[illegible]	33987
Item ... y.	−20 55 43	324 42 14	0·17319n	−∞	8·79404	8·94404n	8·42953	7·97617	9·95384	9·40811n	[illegible]	40176
Item ... y.	−19 31 53	324 53 38	0·36361	−∞	8·78467n	8·93774n	8·74148	8·09732	9·93410	9·37169n	[illegible]	41176
Item ... y.	−16 54 18	326 4 29	0·87967	−∞	8·74684n	8·91009n	9·01422	8·62390	9·80710	9·21210n	[illegible]	39905
Item ... y.	−15 4 47	326 43 2	9·07918	−∞	8·71196n	8·89476n	9·12452	8·76148	[illegible]	9·59497n	[illegible]	39123
Item ... y.	[illegible]13 18 31	327 15 35	0·69636n	−∞	8·66981n	8·86162n	9·20177	8·86087	[illegible]	[illegible]	[illegible]	38316
Item ... y.	9 41 38	328 8 9	1·09760n	−∞	8·55122n	8·75772n	9·30621	8·99965	9·68611	8·86041n	[illegible]	[illegible]
Item ... y.	−5 19 12	329 4 5	0·65418n	−∞	8·30138n	8·52378n	9·37250	9·10066	[illegible]	8·12807n	[illegible]	34093
Item ... y.	−3 51 14	329 10 27	0·53148n	−∞	8·16447n	8·38690n	9·38552	9·11754	[illegible]	7·93836n	[illegible]	33875
Item ... y.	−1 52 59	329 23 54	0·91222n	−∞	7·85414n	8·08223n	9·39509	9·13520	8·99321	7·49161n	[illegible]	33047
Item ... y.	+0 25 45	329 35 31	9·88081	−∞	7·21079	7·44224	9·39680	9·14382	8·35113n	6·68151	[illegible]	32176
Item ... y.	+2 30 18	329 21 25	0·71433n	−∞	7·97799	8·20536	9·39769	9·13130	9·11659n	7·64421	[illegible]	33193
Item ... y.	+5 52 10	331 10 44	1·17026	−∞	8·31413	8·57361	9·34735	9·14917	9·48144n	8·27257n	[illegible]	22547
Item ... y.	+10 21 5	333 3 12	1·11461	−∞	8·50879	8·80262	9·24500	9·10796	9·71182n	8·91931n	[illegible]	06568
Item ... y.	+13 35 45	3[illegible] 6 17	1·08063	−∞	8·62780	8·88350	9·15863	8·95790	9·82291n	8·58511n	[illegible]	20040
Item ... y.	+16 16 53	328 52 7	1·14983	−∞	8·70521	8·92418	9·03819	8·75904	9·88852n	9·06175	[illegible]	30217
Item ... y.	+[illegible] 3 15	325 37 46	1·25018	−∞	8·77962	8·94459	8·64587	8·23587	9·94651n	9·31375	[illegible]	38810
Item ... y.	+23 59 44	322 51 50	1·21801	−∞	8·81041	8·43111	8·59778n	8·04727n	9·97677n	9·57031	0·20168n	41531
Item ... y.	+[illegible] 14 6	321 35 27	0·82347	−∞	8·79453	8·89535	9·06168n	8·43129n	9·99205n	9·66521	[illegible]	40127
Item ... y.	+3[illegible] 24 46	319 55 8	9·91381	−∞	8·74962	8·82456	9·28463n	8·52373n	9·98931n	9·75503	9·05051n	38332
Item ... y.	+33 19 42	318 43 1	0·66087n	−∞	8·66201	8·71851	9·42083n	8·53634n	9·98031n	9·80684	9·77715n	35315
Item ... y.	+34 44 35	318 18 37	9·50515	−∞	8·59492	8·64521	9·47270n	8·53737n	9·97534n	9·82170	9·76612n	33452
Item ... y.	+36 50 47	320 32 37	0·69810	−∞	8·41895	8·50352	9·53205n	8·82420n	0·00592n	9·73833	9·88853n	27835
Item ... y.	+39 16 53	324 2 2	9·81291n	−∞	8·01314	8·15242	9·57934n	9·09297n	0·03459n	9·54371	9·03898n	17554
Item ... y.	+42 46 8	328 55 37	9·49136	−∞	8·05695n	8·27692n	9·61607n	9·33905n	0·03984n	8·79003	0·11638n	9·95015
Item ... y.	+46 46 18	335 41 36	0·72099n	−∞	8·48711n	8·83231n	9·60076n	9·54583n	9·99130n	9·47881n	0·10549n	9·20861

Stations and observed elements	Log. coef. $\Delta g^{3,0}$.	Log. coef. $\Delta g^{3,1}$.	Log. coef. $\Delta h^{3,1}$.	Log. coef. $\Delta g^{3,2}$.	Log. coef. $\Delta h^{3,2}$.	Log. coef. $\Delta g^{3,3}$.	Log. coef. $\Delta h^{3,3}$.	Log. coef. $\Delta g^{2,0}$.	Log. coef. $\Delta g^{2,1}$.	Log. coef. $\Delta h^{2,1}$.	Log. coef. $\Delta g^{2,2}$.	Log. coef. $\Delta h^{2,2}$.	Log. coef. $\Delta g^{1,0}$.	Log. coef. $\Delta g^{1,1}$.	Log. coef. $\Delta h^{1,1}$.
Atlantic Ocean ... z.	9·85059	8·92931n	8·85892	9·34187n	0·15022	0·19461n	0·41360n	9·69178n	9·93311n	9·86272	9·60247	0·39082n	9·91549n	0·14256	0·07217n
Item ... z.	9·85145	8·90285n	8·76661	9·62103n	0·11740	9·97929n	0·45552n	9·68273n	9·96177n	9·82553	9·80034	0·37771n	9·91078n	0·16693	0·03069n
Item ... z.	9·82930	9·34394n	9·19394	9·61723n	0·07029	9·95139n	0·49022n	9·79643n	9·91218n	9·76218	9·93937	0·39213n	9·85395n	0·18317	0·03317n
Item ... z.	9·81483	9·43474n	9·28167	9·60463n	0·04832	9·04672n	0·50913n	9·82261n	9·88375n	9·73528	9·95525	0·39621n	9·82520n	0·18869	0·03502n
Item ... z.	9·77780	9·56420n	9·39195	9·60365n	9·99397	9·85429n	0·53329n	9·87291n	9·84047n	9·66812	0·01514	0·40016n	9·76460n	0·20081	0·02856n
Item ... z.	9·74345	9·63066n	9·44786	9·58642n	9·94946	9·78946n	0·54996n	9·90143n	9·79912n	9·61632	0·04625	0·40929n	9·71626n	0·20800	0·02320n
Item ... z.	9·70212	9·68245n	9·40064	9·55855n	9·89945	9·72183n	0·56209n	9·92480n	9·75225n	9·51014	0·07152	0·41242n	9·66312n	0·21407	0·02220n
Item ... z.	9·58555	9·75947n	9·35297	9·46202n	9·76863	9·57571n	0·58440n	9·96136n	9·62634n	9·31984	0·11068	0·41790n	9·52743n	0·22385	0·01730n
Item ... z.	9·34108	9·81551n	9·59311	9·23963n	9·51387	9·28453n	0·59593n	9·98864n	9·37579n	9·13339	0·14693	0·41877n	9·26819n	0·23254	0·01[illegible]4n
Item ... z.	9·20445	9·82604n	9·60181	9·10410n	9·37208	9·23486n	0·59871n	9·99406n	9·23746n	9·01323	0·15110	0·41966n	9·12840n	0·23391	0·00968n
Item ... z.	8·89609	9·83536n	9·60727	8·80105n	9·06094	9·09965n	0·60116n	9·99858n	8·92842n	8·70033	0·15944	0·41933n	8·81770n	0·23569	0·00760n
Item ... z.	8·25431n	9·83868n	9·60723	8·16455	8·41753n	8·93200n	0·60193n	9·99992n	8·18728	8·05583n	0·16517	0·41815n	9·17547	0·23675	0·00530n
Item ... z.	9·01953n	9·83310n	9·60582	8·92340	9·18470n	9·12820n	0·60058n	9·99750n	9·05103	8·82456n	0·15792	0·41970n	8·94157	0·23530	0·00793n
Item ... z.	9·38231n	[illegible]	9·50057	9·33574	9·53392n	9·38552	0·59109n	9·98615n	9·42712	9·16764n	0·20108	0·39070n	9·31074	0·24132	9·08184n
Item ... z.	9·61070n	9·76960n	9·43577	9·61206	9·74970n	9·78261	0·55130n	9·95576n	9·67459	9·38070n	0·23321	0·37050n	9·55554	0·24599	9·95516n
Item ... z.	9·70944n	9·69255n	9·43455	9·67531	9·87004n	9·32651	0·50431n	9·92127n	9·77823	9·52130n	0·17915	0·37088n	9·67223	0·23604	9·97284
Item ... z.	9·76695n	9·60098n	9·38201	9·68107	9·90120n	9·32121n	0·54708n	9·88320n	9·83953	9·62560n	0·10942	0·38150n	9·74874	0·21573	9·60670n
Item ... z.	9·82068n	9·40755n	9·24258	9·64231	0·05231n	9·87635n	0·59110n	9·81105n	9·90181	9·73684n	9·98219	0·39010n	9·83621	0·19654	0·00557n
Item ... z.	9·84042n	9·00369n	8·88292	9·56571	0·11623n	0·04670n	0·45372n	9·70230n	9·94866	9·82796n	0·83153	0·38140n	9·91027	0·16333	0·04207n
Item ... z.	9·85428n	8·41964	8·31882n	9·51853	0·14802n	[illegible]	0·40547n	9·57019n	9·98071	0·87080n	9·73207	0·36460n	9·96155	0·14410	0·04378n
Item ... z.	9·84266n	9·17111	9·09617n	9·41045	0·17135n	0·11139n	0·34570n	9·36446n	0·00086	9·92502n	9·58114	0·34140n	0·00530	0·12050	0·04556n
Item ... z.	9·81634n	9·40809	9·35159n	9·20775	0·18224n	0·13381n	0·28728n	8·97446n	0·01491	9·95841n	9·43288	0·31770n	0·04096	0·09889	[illegible]4230n
Item ... z.	9·79754n	9·48607	9·43578n	9·24900	0·18439n	0·16557n	0·25921n	8·40959n	0·02081	[illegible]	9·31833	0·30066n	0·05682	0·08893	[illegible]3864n
Item ... z.	9·76060n	9·59604	9·51147n	9·47039	0·17824n	9·98557n	0·25616n	8·89691	0·04594	9·96130n	9·56753	0·27[illegible]n	0·07895	0·09193	0·00736n
Item ... z.	9·70275n	9·70183	9·56255n	9·67264	0·15911n	9·75592n	0·24680n	9·30675	0·07751	9·93673n	9·74621	0·23268n	0·10252	0·09793	9·93865n
Item ... z.	9·57666n	9·81735	9·50738n	9·83407	0·11196n	8·91862n	0·19813n	9·58335	0·16750	9·88753n	9·80813	0·15170n	0·13293	0·09951	9·87954n
Item ... z.	9·30389n	9·91705	9·57185n	9·05652	0·01145n	9·17687	0·08676n	9·77284	0·13495	9·78675n	9·09907	0·02400n	0·16354	0·09635	9·[illegible]311n
Item ... y.	−∞	8·29717	8·36736	9·86950	9·08115	0·32807n	0·10936	−∞	9·42591	9·49630	0·25524n	9·46109n	−∞	9·81145n	9·88184n
Item ... y.	−∞	8·20574	8·34198	9·85756	9·36119	0·37137n	9·80504	−∞	9·38960	9·52584	0·27881n	9·74744n	−∞	9·77085n	9·90[illegible]n
Item ... y.	−∞	8·62152	8·77152	9·79890	9·34584	0·40092n	9·85519	−∞	9·31470	9·46470	0·24508n	9·79702n	−∞	9·76168n	9·91178n
Item ... y.	∞	8·70535	8·85842	9·77303	9·32907	0·40993n	9·84751	−∞	9·28390	9·43697	0·24886n	9·80400n	−∞	9·75973n	9·91280n
Item ... y.	−∞	8·80967	8·98134	9·71212	9·32180	0·43913n	9·74853	−∞	9·21028	9·38255	0·24855n	9·85[illegible]n	−∞	9·74671n	9·91801n
Item ... y.	−∞	8·86102	9·04382	9·66365	9·30061	0·44024n	9·67974	−∞	9·15462	9·33741	0·24842n	9·88[illegible]n	−∞	9·73930n	9·92219n
Item ... y.	−∞	8·90041	9·09122	9·61125	9·26935	0·41698n	9·60[illegible]2	−∞	9·09515	9·28696	0·24816n	9·90[illegible]n	−∞	9·73360n	9·92[illegible]8n
Item ... y.	−∞	8·95715	9·16365	9·47384	9·16723	0·45974n	9·63061	−∞	8·94890	9·15546	0·24744n	9·94[illegible]3n	−∞	9·72256n	9·92906n
Item ... y.	−∞	8·99292	9·21532	9·21171	8·93987	0·47286n	9·10146	−∞	8·67814	8·90053	0·24453n	9·972[illegible]n	−∞	9·71098n	9·93338n
Item ... y.	−∞	9·00073	9·22316	9·07203	8·80405	0·47475n	9·11090	−∞	[illegible]	8·75951	0·24457n	9·97[illegible]n	−∞	9·70963n	9·93386n
Item ... y.	−∞	9·00544	9·23353	8·76014	8·50025	0·47645n	8·97394	−∞	8·22314	8·45153	0·24347n	9·98[illegible]n	−∞	9·70677n	9·93486n
Item ... y.	∞	9·00518	9·23063	8·11651n	7·86333n	0·47700n	[illegible]	−∞	[illegible]	[illegible]	[illegible]	9·98[illegible]n	−∞	9·70478n	9·93573n
Item ... y.	−∞	9·00417	9·23154	8·88417n	8·62278n	0·47605n	9·00367	−∞	[illegible]	8·57522n	[illegible]	9·9822[illegible]n	∞	9·70731n	9·93468n
Item ... y.	−∞	8·96079	9·22027	9·23517n	9·03699n	0·47103n	9·26280n	−∞	[illegible]	8·95228n	[illegible]	0·02728n	−∞	9·68309n	9·94257n
Item ... y.	−∞	8·88083	9·17466	9·45579n	9·31875n	0·45731n	9·66480n	−∞	[illegible]	9·20459n	0·20128n	0·06401n	−∞	9·65620n	9·95008n
Item ... y.	−∞	8·84473	9·10283	9·58733n	9·38660n	0·45171n	9·21391n	−∞	[illegible]	9·31347n	0·21613n	[illegible]	−∞	9·68415n	9·94225n
Item ... y.	−∞	8·79772	9·01669	9·67796n	9·39881n	0·44081n	9·21404	−∞	9·16121n	9·38018n	0·23025n	9·95110n	−∞	9·71350n	9·93247n
Item ... y.	−∞	8·66768	8·83265	9·77844n	9·36844n	0·41133n	9·77857	−∞	9·28688n	9·45185n	0·24326n	9·83226n	−∞	9·75170n	9·91667n
Item ... y.	−∞	8·32019	8·44089	9·85445n	9·30394n	0·36753n	9·96107	−∞	0·39010n	[illegible]	0·24521n	9·69470n	−∞	9·78086n	9·90150n
Item ... y.	−∞	7·76779n	7·86861n	9·89892n	9·26853n	0·33153n	0·00469	−∞	9·45380n	9·55402n	[illegible]	[illegible]	∞	[illegible]	9·89410n
Item ... y.	−∞	8·55838n	8·63332n	9·93459n	9·17369n	0·28504n	0·05070	−∞	9·51307n	9·58801n	0·23032n	9·46542n	∞	9·80880n	9·88374n
Item ... y.	−∞	8·82757n	8·88407n	9·95925n	9·07476n	0·24038n	0·06691	−∞	9·55933n	9·61583n	0·21932n	9·33483n	−∞	9·81940n	9·87590n
Item ... y.	−∞	8·91900n	8·96929n	9·96864n	9·03331n	0·21955n	0·06401	∞	9·57868n	9·62897n	0·21785n	9·27752n	−∞	9·82289n	9·87318n
Item ... y.	−∞	9·00619n	9·09076n	9·97399n	9·26614n	0·22800n	9·96041	−∞	9·58103n	9·66560n	0·19607n	9·48822n	∞	9·80511n	9·88768n
Item ... y.	−∞	9·07273n	9·21201n	9·96932n	9·48285n	0·25310n	9·74222	−∞	9·57033n	9·70963n	0·16783n	9·68136n	−∞	9·76886n	9·90814n
Item ... y.	−∞	9·12957n	9·34954n	9·94521n	9·66819n	0·20794n	8·95813	−∞	9·54466n	9·76463n	0·11331n	9·83629n	−∞	9·71276n	9·93273n
Item ... y.	−∞	9·13416n	9·47936n	9·87439n	9·81946n	0·12879n	9·61630n	−∞	9·47700n	9·82270n	0·01188n	9·95695n	−∞	9·61449n	9·95969n

PRIMARY EQUATIONS FOR THE CORRECTIONS OF THE GAUSSIAN CONSTANTS FOR 1829 (Continued).

Stations and observed elements.		Latitude.	Long. East, Greenwich.	Log. n.	Log. coef. $\Delta g^{4,0}$.	Log. coef. $\Delta g^{4,1}$.	Log. coef. $\Delta h^{4,1}$.	Log. coef. $\Delta g^{4,2}$.	Log. coef. $\Delta h^{4,2}$.	Log. coef. $\Delta g^{4,3}$.	Log. coef. $\Delta h^{4,3}$.
		° ′ ″	° ′ ″								
Atlantic Ocean	x.	−24 18 17	319 37 25	1·50691	9·58979	8·92335	8·85296n	8·98644n	9·77479	9·14126n	9·36025n
Item	z.	−24 33 43	323 50 35	1·63599	9·58757	8·98070	8·84445n	9·26282n	9·75919	8·90821n	9·38444n
Item	z.	−20 55 43	324 42 14	1·86064	9·60468	7·09362n	6·94362	9·29409n	9·74715	9·06827n	9·61400n
Item	x.	−19 31 53	324 53 38	1·85003	9·60126	8·58876n	8·43569	9·29253n	9·73649	9·11306n	9·67547n
Item	z.	16 54 18	326 4 29	2·01586	9·58301	9·03626n	8·86401	9·31024n	9·70056	9·09211n	9·77311n
Item	x.	15 4 45	326 43 2	1·70775	9·55941	9·19133n	9·00853	9·30385n	9·66789	9·06556n	9·82606n
Item	x.	−13 18 31	327 15 35	1·98650	9·52698	9·29672n	9·10491	9·28508n	9·62598	9·02815n	9·86841n
Item	z.	9 41 38	328 8 9	1·63919	9·42448	9·43738n	9·23088	9·20312n	9·50973	9·10958n	9·93031n
Item	z.	− 5 19 12	329 4 5	1·68780	9·19059	9·53073n	9·30833	8·99127n	9·26311	8·66914n	9·98054n
Item	x.	− 3 51 14	329 10 27	1·62377	9·05592	9·54793n	9·32370	8·35860n	9·12658	8·62585n	9·98970n
Item	z.	− 1 52 59	329 23 54	0·85612	8·74920	9·56264n	9·33455	8·55742n	8·81731	8·49594n	9·99745n
Item	z.	+ 0 25 42	329 35 31	0·99211	8·10856n	9·56752n	9·33607	7·92148	8·17447n	8·32985n	9·99978n
Item	x.	+ 2 30 18	329 21 25	0·80956	8·87233n	9·55917n	9·33180	8·67932	8·94071n	8·52322n	9·99560n
Item	x.	+ 5 52 10	331 10 44	1·53968	9·23080n	9·53214n	9·27266	9·08696	9·28514n	8·76718	9·99605n
Item	z.	+10 21 5	333 3 12	1·31492	9·44748n	9·43892n	9·14509	9·35149	9·48853n	9·12764	9·92615n
Item	z.	+13 35 45	331 6 12	1·23601	9·53297n	8·29946n	9·04136	9·40042	9·60115n	8·62831	9·86611n
Item	x.	+16 16 55	328 52 7	1·03902	9·57600n	9·10891n	8·88094	9·39257	9·67172n	8·57299n	9·79976n
Item	z.	+20 3 15	325 37 46	1·00647	9·60782n	8·39854n	8·23357	9·32636	9·73636n	9·02543n	9·65819n
Item	x.	+23 59 44	322 51 50	1·05652	9·59225n	8·90121	8·78051n	9·21355	9·76406n	9·01348n	9·41094n
Item	x.	+27 14 6	321 35 27	0·62634	9·55225n	9·20328	9·10246n	9·12827	9·75806n	8·73784n	9·06468n
Item	z.	+30 24 46	319 55 8	0·41162n	9·47801n	7·35654	9·28160n	8·97337	9·73427n	7·96665	8·20097
Item	x.	+33 19 47	318 43 1	1·22634n	9·36663n	9·44567	9·38917n	8·80642	9·69091n	8·90702	9·08049
Item	z.	+34 44 35	318 18 37	0·51118n	9·28881n	9·47761	9·42732n	8·72644	9·66177n	9·06458	9·21822
Item	x.	+36 50 47	320 32 37	1·32035n	9·12106n	9·53237	9·44708n	8·89312	9·60097n	9·12524	9·39283
Item	x.	+39 16 53	3[illegible] 2 2	1·15927n	8·73510n	9·58473	9·44545n	9·01581	9·50228n	9·04570	9·53658
Item	x.	+42 46 8	328 55 37	1·25888n	8·81200	9·63125	9·41128n	9·01190	9·28892n	8·40756	9·65737
Item	z.	+46 46 18	335 41 36	1·51215n	9·31031	9·65147	9·30627n	8·72810	8·78309n	9·18981n	9·70230
Item	x.	+47 55 8	345 9 42	1·54654n	9·38610	9·66870	9·09182n	8·55094	8·30670n	9·58596n	9·57861
Item	x.	+49 15 50	351 57 42	0·36173	9·45927	9·66539	8·81530n	7·71185n	7·17153	9·70240n	9·35321
Motherbank	x.	+50 44 20	358 52 54	1·22011	9·52563	9·64948	7·93997n	8·71022n	7·33172	9·74738n	8·51544
Atlantic Ocean	x.	+47 55 8	345 9 42	1·87662	9·61826n	9·46878	8·89140n	7·90095	9·65671n	9·90119	9·80584n
Item	z.	+49 15 50	351 57 42	1·68485	9·58422n	9·55190	8·60180n	9·94567	9·40535n	9·98272	9·63363n
Motherbank	z.	+50 44 10	358 52 54	1·86398	9·53631n	9·62186	7·91234n	9·96083	8·55253n	9·99105	8·75911n
Atlantic Ocean	y.	+47 55 8	345 9 42	1·53007	−∞	8·36624n	8·94312n	9·43258n	9·67682n	9·84580n	9·35315n
Item	y.	+49 15 50	351 57 42	1·41347	−∞	8·18820n	9·03829n	9·19278n	9·73310n	9·59705n	9·94624n
Motherbank	y.	+50 44 20	358 52 54	1·03822	−∞	7·41207n	9·12158n	8·35328n	9·76158n	8·73505n	9·96789n
North Sea	i.	+51 36 41	2 18 15	1·72578	9·58365n	9·37548n	8·71600	9·43823	9·38256	9·73296	9·56427
Item	i.	+56 11 24	4 36 56	0·96347n	9·70570n	8·95856n	8·86274	9·63043	9·47929	9·79127	9·65447
Sound near Copenhagen	i.	+55 43	12 35 14	1·32080n	9·69340n	9·01072n	8·62325	9·56050	9·57206	9·65186	9·80557
Baltic	i.	+58 2 23	19 34 40	1·23158n	9·69671n	8·62941n	8·65801	9·49094	9·64611	9·31705	9·83537
Gulf of Finland	i.	+60 4 54	28 7 47	0·86850n	9·72395n	8·02531	8·73078	9·35005	9·69966	8·84323	9·81265
Small Harbour of Cronstadt	i.	+59 58 40	29 46 24	0·46580n	9·72198n	7·95904	8·69461	9·31702	9·70569	8·91487	9·81291

Stations and observed elements.	Log. coef. $\Delta g^{4,4}$.	Log. coef. $\Delta h^{4,4}$.	Log. coef. $\Delta g^{3,0}$.	Log. coef. $\Delta g^{3,1}$.	Log. coef. $\Delta h^{3,1}$.	Log. coef. $\Delta g^{3,2}$.	Log. coef. $\Delta h^{3,2}$.	Log. coef. $\Delta g^{3,3}$.	Log. coef. $\Delta h^{3,3}$.	Log. coef. $\Delta g^{2,0}$.	Log. coef. $\Delta g^{2,1}$.	Log. coef. $\Delta h^{2,1}$.	Log. coef. $\Delta g^{2,2}$.	Log. coef. $\Delta h^{2,2}$.	Log. coef. $\Delta g^{1,0}$.	Log. coef. $\Delta g^{1,1}$.	Log. coef. $\Delta h^{1,1}$.
Atlantic Ocean	0·07257n	9·59692n	8·92257n	9·72465n	9·65426	8·85745	9·64580n	9·74474n	9·94343n	9·87518n	9·70217	9·63178n	9·38115	9·86950n	9·95969	9·49630	9·42591n
Item	0·00862n	9·85984n	8·87082n	9·75158n	9·61534	9·12415	9·62052n	9·51419n	9·99052n	9·87859n	9·72296	9·58672n	9·30119	9·85756n	9·95831	9·52584	9·38960n
Item	9·95768n	9·85321n	9·30722n	9·72410n	9·57410	9·28232	9·73538n	9·40511n	9·95384n	9·82431n	9·78381	9·63381n	9·34584	9·79890n	9·97036	9·40470	9·31470n
Item	9·93593n	9·86523n	9·39700n	9·70758n	9·55451	9·32649	9·77045n	9·37169n	9·93410n	9·79946n	9·80292	9·64985n	9·32[illegible]	9·77303n	9·97420	9·43607	9·28390n
Item	9·86182n	9·85220n	9·52030n	9·67176n	9·49951	9·43012	9·82044n	9·21210n	9·89310n	9·74542n	9·83850	9·66625n	9·[illegible]180	9·71212n	9·98082	9·38255	9·21028n
Item	9·80646n	9·83483n	9·58353n	9·63779n	9·45499	9·48579	9·84883n	9·09497n	9·85547n	9·70104n	9·85973	9·67623n	9·[illegible]61	9·66365n	9·98478	9·33742	9·15462n
Item	9·74525n	9·86750n	9·63264n	9·59681n	9·40500	9·53104	9·87194n	8·97081n	9·81107n	9·65129n	9·87622	9·68441n	9·26035	9·61025n	9·98817	9·28666	9·09516n
Item	9·59376n	9·70946n	9·70547n	9·48075n	9·27425	9·60116	9·90777n	8·80541n	9·68614n	9·52119n	9·90369	9·69719n	9·16023	9·47384n	9·99376	9·15546	8·94896n
Item	9·30809n	9·48358n	9·75719n	9·23784n	9·01544	9·66033	9·93717n	8·15862n	9·41007n	9·26632n	9·92585	9·70345n	8·93987	9·21171n	9·99813	8·96054	8·67814n
Item	9·16621n	9·34867n	9·76724n	9·09926n	8·87563	9·66963	9·93761n	7·93836n	9·30221n	9·12751n	9·92997	9·70569n	8·86405	9·07203n	9·99902	8·75954	8·53709n
Item	8·84714n	9·04452n	9·77556n	8·79331n	8·56522	9·68114	9·94103n	7·49161n	8·99321n	8·81747n	9·93397	9·70583n	8·50025	8·76014n	9·99977	8·45153	8·22344n
Item	8·19600	8·46661	9·77801n	8·15156	7·92011n	9·68798	9·94096n	6·68151	8·35144	8·17546	9·93568	9·70425n	7·86353n	8·11651	9·99999	7·80917n	7·57872
Item	8·97246	9·16705	9·77357n	8·91651	8·68914n	9·67872	9·94011n	7·64421	9·11659	8·94116	9·93301	9·70564n	8·62278n	8·88417	9·99959	8·57522n	8·34783
Item	9·23843	9·56120	9·75254n	9·28846	9·02898n	9·71240	9·91068n	8·27257n	9·48144	9·30846	9·93339	9·67591n	9·03690n	9·23517	9·99712	8·95223n	8·69280
Item	9·32019	9·81404	9·69458n	9·52746	9·33363n	9·71919	9·85627n	8·91931n	9·71182	9·54842	9·92109	9·62726n	9·31875n	9·45579	9·99288	9·20459n	8·91070
Item	9·57160	9·89042	9·62536n	9·62185	9·36375n	9·63565	9·83638n	8·55511n	9·82291	9·65989	9·89139	9·63320n	9·38060n	9·58733	9·98766	9·31345n	9·05535
Item	9·74983	9·91232	9·54357n	9·67336	9·45439n	9·53328	9·8[illegible]43n	8·66175	9·88[illegible]2	9·73097	9·85820	9·63923n	9·39821n	9·67796	9·98223	9·38[illegible]	9·16121
Item	9·92328	9·88558	9·36594n	9·71837	9·55340n	9·34329	9·75329n	9·31175	9·94651	9·80905	9·80623	9·63526n	9·36844n	9·77844	9·97284	9·45185n	9·28688
Item	0·02455	9·81092	8·97719n	9·74223	9·62153n	9·09598	9·64649n	9·5[illegible]031	9·97677	9·87101	9·72715	9·60645n	9·30304n	9·85445	9·96074	9·51080n	9·39010
Item	0·06179	9·75693	8·40060	9·75099	9·65017n	8·87718	9·50757n	9·66521	9·99205	9·91052	9·65839	9·55757n	9·26853n	9·89892	9·94897	9·55462n	9·45380
Item	0·08539	9·64078	9·16243	9·74381	9·60887n	8·53286	9·29376n	9·75503	9·98931	9·94103	9·57187	9·49693n	9·17360n	9·93459	9·93573	9·58801n	9·51301
Item	0·09308	9·51708	9·40725	9·72786	9·67136n	8·00877	8·89326n	9·80684	9·98031	9·96292	9·47386	9·41736n	9·01760n	9·95925	9·92196	9·61583n	9·55933
Item	0·09031	9·46190	9·48795	9·71735	9·66706n	7·38625	8·32158n	9·82170	9·97534	9·97154	9·41779	9·36750n	9·03331n	9·96864	9·91472	9·62807n	9·57863
Item	0·05620	9·66645	9·58342	9·71526	9·63069n	8·08405n	8·79190	9·73833	0·00592	9·98217	9·33606	9·25149n	9·26614n	9·97399	9·9[illegible]322	9·66560n	9·58103
Item	9·97703	9·84747	9·66875	9·70852	9·56924n	8·68686n	9·17333	9·54171	0·03459	9·99128	9·20545	9·06617n	9·48287n	9·96932	9·88876	9·70964n	9·57[illegible]35
Item	9·78[illegible]	9·94828	9·75968	9·67669	9·45672n	9·11880n	9·39582	8·79003	0·03984	9·99868	8·82372	8·60375n	9·66819n	9·94521	9·86575	9·76463n	9·54460
Item	9·07112	9·96800	9·83242	9·60558	9·26038n	9·42877n	9·48370	9·47881n	9·99130	9·99917	8·75070n	8·40550	9·81946n	9·87439	9·83563	9·82230n	9·41700
Item	9·63850n	9·88581	9·84842	9·59411	9·01723n	9·57977n	9·33553	9·85315n	9·84580	9·99774	8·99262n	8·41574	9·93668n	9·69244	9·82619	9·85579n	9·27801
Item	9·85310n	9·65157	9·86178	9·55426	8·70417n	9·65610n	9·11578	9·91924n	9·59705	9·99517	9·16682n	8·31673	9·97785n	9·43753	9·81463	9·87522n	9·02513
Motherbank	9·89356n	8·78695	9·87994	9·49253	7·78302n	9·70324n	8·29494	9·96789n	8·73595	9·99123	9·29874n	7·58923	9·99990n	8·58260	9·80131	9·88886n	8·17920
Atlantic Ocean	9·71110	9·93839n	9·16411n	9·95863	9·38175n	0·06390	9·81966n	9·93376	9·92641n	9·81428	0·15910	9·58222n	0·16844	9·82420n	0·17155	0·11249	9·33361n
Item	9·88518	9·68355n	8·89209n	9·98543	9·13534n	0·09351	9·55319n	0·00630	9·65721n	9·85880	0·16697	9·31688n	0·18906	9·54874n	0·18054	0·11137	9·26178n
Motherbank	9·90289	8·79628n	7·20412n	0·00480	8·29528n	0·09324	8·68494n	0·00525	8·77331n	9·90226	0·16724	8·45772n	0·17941	8·67111n	0·18992	0·10226	8·39274n
Atlantic Ocean	0·01529n	9·28798n	−∞	8·95350n	9·53038n	9·69244n	9·93668n	9·97528n	9·98263n	−∞	9·27891n	9·85579n	9·82192n	0·06616n	−∞	9·40839n	9·98527n
Item	9·77101n	9·97364n	−∞	8·71865n	9·56874n	9·43753n	9·97785n	9·71154n	0·06673n	−∞	9·02513n	9·87522n	9·55812n	0·09834n	−∞	9·14562n	9·99511n
Motherbank	8·89800n	0·04467n	−∞	7·89192n	9·60143n	8·58260n	9·99090n	8·84706n	0·07900n	−∞	8·17930n	9·88881n	8·09371n	0·10201n	−∞	8·29041n	9·99992n
North Sea	9·72600	9·56714	9·74981n	8·71349	9·24895	9·82360	9·62128	9·86086	9·67788	9·65648n	9·77735	9·55096	9·00034	9·73560	8·65706	0·00083	9·66500
Item	9·73094	9·65581	9·78533n	9·38256	9·31197	9·89686	9·68151	9·89342	9·74304	9·65128n	9·88036	9·57357	9·[illegible]1093	9·77115	8·81690	0·02231	9·664[illegible]
Sound near Copenhagen	9·68949	9·81511	9·79560n	9·37548	9·30557	9·83942	9·80257	9·76185	9·90515	9·65398n	9·87256	9·62500	9·95770	9·90369	9·11860	0·01649	9·73312
Baltic	8·46[illegible]9n	9·78419	9·78561n	9·45743	9·36586	9·73815	9·86207	9·41747	9·92184	9·61982n	9·87268	9·68088	9·84029	9·95323	9·01787	9·99559	9·78211
Gulf of Finland	9·41830n	9·63053	9·77342n	9·38881	9·35315	9·57241	9·90048	8·57519n	9·88902	9·58894n	9·86374	9·73207	9·75959	9·98200	9·04844	9·96965	9·82614
Small Harbour of Cronstadt	9·47669n	9·62066	9·77488n	9·39568	9·35793	9·54095	9·90815	8·91803n	9·88997	9·59062n	9·86010	9·73846	9·63083	9·99065	9·05423	9·96656	9·83404

FINAL EQUATIONS FOR THE CORRECTIONS OF THE 24 GAUSSIAN CONSTANTS, RESULTING FROM 610 MAGNETIC ELEMENTS OBSERVED IN THE YEARS 1828 TO 1830.

	$\Delta g^{4.0}$.	$\Delta g^{4.1}$.	$\Delta h^{4.1}$.	$\Delta g^{4.2}$.	$\Delta h^{4.2}$.	$\Delta g^{4.3}$.	$\Delta h^{4.3}$.	$\Delta g^{4.4}$.	$\Delta h^{4.4}$.	$\Delta g^{3.0}$.	$\Delta g^{3.1}$.	$\Delta h^{3.1}$.	$\Delta g^{3.2}$.	$\Delta h^{3.2}$.	$\Delta g^{3.3}$.	$\Delta h^{3.3}$.	$\Delta g^{2.0}$.	$\Delta g^{2.1}$.	$\Delta h^{2.1}$.	$\Delta g^{2.2}$.	$\Delta h^{2.2}$.	$\Delta g^{1.0}$.	$\Delta g^{1.1}$.	$\Delta h^{1.1}$.
725·16 =	+ 54·3353	+ 0·2529	+ 7·3710	+ 4·1917	− 11·7069	− 2·2304	− 3·8111	− 19·5562	− 17·4553	+ 47·4200	− 0·4012	+ 10·1200	+ 8·0118	− 15·0235	+ 22·1167	− 28·4275	+ 25·2273	− 8·2861	− 31·8097	+ 20·4469	− 10·1048	+ 14·9021	− 11·4231	− 42·2356
− 619·28 =	+ 0·2529	+ 34·9167	+ 4·5406	− 2·2767	+ 21·9510	+ 5·8437	+ 1·8232	− 7·2218	− 22·3895	+ 1·3014	+ 33·0997	+ 4·8254	− 5·8373	+ 43·2241	+ 3·0110	+ 7·9719	+ 1·9485	+ 23·9173	+ 1·0748	− 11·7988	+ 10·8090	+ 1·5337	+ 29·5294	− 1·2964
723·41	+ 7·3710	+ 4·5406	+ 47·8097	− 23·2279	− 0·8719	+ 6·1822	− 20·4717	+ 6·1005	− 26·0215	+ 19·2450	+ 4·9311	+ 48·3232	− 20·0082	+ 3·8193	+ 16·6367	+ 10·1038	+ 82·2458	+ 1·4030	+ 49·3404	− 27·6312	+ 3·7562	+ 92·6496	− 0·9272	+ 31·9533
992·32 =	+ 4·1917	− 2·2767	− 23·2279	+ 67·5788	− 5·4586	− 1·7831	+ 39·7251	− 6·3640	− 3·3573	− 3·4840	− 4·4713	− 33·0834	+ 66·9339	− 6·6530	+ 6·2834	+ 49·2086	− 19·9280	+ 2·9386	− 65·0305	+ 80·4974	+ 7·7196	− 28·2315	− 5·7792	− 44·4576
+ 335·16 =	− 11·7069	+ 21·9510	− 0·8719	− 5·4586	+ 106·3771	− 47·2216	+ 4·7147	+ 18·9315	− 32·9670	− 4·6220	+ 7·3895	− 4·9707	− 6·1487	+ 82·9148	− 63·2669	+ 4·0373	+ 10·3122	+ 66·6465	− 2·1471	+ 8·5564	+ 66·5285	+ 17·5707	+ 66·6874	+ 9·9717
18·590	− 2·2304	+ 5·8437	+ 6·1822	− 1·7831	− 42·2216	+ 182·9105	− 8·9822	− 11·1866	+ 18·3749	− 17·2631	− 10·3497	− 9·0877	− 12·6693	+ 35·2497	+ 88·7598	− 11·9611	− 6·8541	− 64·4010	− 34·6407	− 8·6918	61·5872	+ 21·6373	30·3242	− 41·2272
+ 2164·74	− 3·8111	+ 1·8232	− 20·4717	+ 39·7251	+ 4·7147	− 8·9822	+ 199·9683	− 54·5557	+ 21·9742	+ 45·7073	+ 2·0890	+ 0·3462	− 6·1519	+ 6·1970	− 12·1175	+ 45·4839	− 13·0367	+ 7·5844	+ 35·5034	+ 74·3765	+ 20·4571	− 76·2811	+ 5·5452	16·2815
+ 3166·33	− 19·5562	− 7·2218	+ 6·1005	− 6·3640	+ 18·9315	− 11·1866	− 54·5557	+ 1119·7794	+ 775·839	− 2·3577	− 27·0160	− 79·3637	− 10·2473	− 36·0188	− 125·7180	+ 598·2705	+ 181·7060	+ 14·0454	− 15·8181	+ 14·0369	− 162·1764	+ 3·7876	+ 84·5546	+ 331·0581
+ 7951·76	− 17·4553	− 22·3895	− 26·0215	− 3·3573	− 32·9670	+ 18·3749	+ 21·9742	+ 775·839	+ 1060·7115	+ 46·8308	+ 48·0830	− 38·6233	+ 11·8660	− 52·2429	− 437·8822	+ 10·8013	+ 68·0324	+ 79·0412	+ 41·8175	+ 88·2634	+ 101·5733	− 41·8180	− 246·4165	+ 128·1702
+ 84·53	+ 47·4200	+ 1·3014	+ 19·2450	− 3·4840	− 4·6220	− 17·2631	+ 45·7073	− 2·3577	+ 46·8308	+ 147·1036	− 2·0834	+ 37·1296	− 3·3584	− 21·5801	− 26·6472	− 28·5630	+ 132·6097	− 5·2947	+ 46·2653	+ 18·7462	28·5557	+ 86·6163	− 14·8216	31·0540
− 1151·89	0·4012	+ 33·0997	+ 4·9311	− 4·4713	+ 7·3895	− 10·3497	+ 2·0890	− 27·0160	+ 48·0830	− 2·0834	+ 94·8025	+ 1·8705	− 0·4610	+ 54·6746	+ 10·3483	+ 5·4170	4·0692	+ 77·0223	+ 9·7145	− 11·7952	+ 98·5700	+ 0·4633	+ 48·0652	+ 0·6839
183·35	+ 10·1200	+ 4·8254	+ 48·3232	− 33·0834	4·9707	− 9·0877	+ 0·3462	− 79·3637	− 38·6233	+ 37·1296	+ 10·8705	+ 125·1877	− 56·5210	1·7727	+ 25·3961	54·4115	+ 47·0076	+ 10·3064	+ 107·2394	− 40·7005	+ 16·4070	+ 150·0633	+ 1·5021	+ 85·4451
195·53 =	+ 8·0118	− 5·8373	− 20·0082	+ 66·9339	− 6·1487	− 12·6693	6·1519	− 10·2473	+ 11·8660	− 3·3584	− 0·4610	− 56·5210	+ 169·7015	− 13·0016	− 9·7831	+ 74·1594	9·9759	+ 6·0358	− 53·4231	+ 107·3407	17·5259	− 34·4533	+ 14·5636	− 83·6846
46·87	− 15·0235	+ 43·2241	+ 3·8193	6·6530	+ 82·9148	+ 35·2497	+ 6·1970	− 36·0188	− 52·2429	− 21·5801	+ 54·6746	− 1·7727	− 13·0016	+ 273·7914	− 60·5974	+ 19·7635	− 6·0251	− 19·2157	− 11·4715	− 17·1124	+ 127·2024	+ 26·5715	+ 103·6081	5·9906
5914·94	+ 22·1167	+ 3·0110	+ 16·6367	+ 6·2834	− 63·2669	+ 88·7598	− 12·1175	− 125·7180	− 437·8822	− 26·6472	+ 10·7483	+ 25·3961	− 9·7831	− 60·5974	+ 771·8434	− 38·7453	55·7942	− 29·9842	39·7791	− 55·3179	+ 333·4931	+ 25·0846	− 107·3886	− 113·1507
996·07 =	− 28·4275	+ 7·9719	+ 10·1038	+ 49·2086	+ 4·0373	− 11·9611	+ 45·4839	+ 598·2705	+ 10·8013	− 28·5630	+ 5·4170	− 54·4115	+ 74·1594	+ 19·7635	− 38·7453	+ 860·2590	+ 139·4921	3·0666	− 16·9860	− 249·4938	11·3057	+ 10·6602	+ 36·1565	+ 132·7150
+ 68·51	+ 25·2273	+ 1·9485	+ 82·2458	− 19·9280	+ 10·3122	− 6·8541	− 13·0367	+ 181·7060	+ 68·0324	+ 132·6097	− 4·9092	+ 47·0076	− 9·9759	− 6·0251	− 55·7942	+ 139·4921	+ 336·3444	− 8·1514	+ 87·6020	− 27·3690	− 41·9859	+ 49·6779	4·3294	+ 87·6357
+ 409·04	− 8·2861	+ 23·9173	+ 1·4030	+ 2·9386	+ 66·6465	− 64·4010	+ 7·5844	+ 14·0454	+ 29·6412	− 5·2947	+ 77·0223	+ 10·3064	+ 6·0358	− 19·2157	− 29·9842	+ 3·0666	− 8·1514	+ 210·8808	+ 21·9138	+ 13·1383	+ 101·6024	7·8700	+ 110·8758	+ 18·3827
+ 4067·11	− 31·8097	+ 1·0748	+ 49·3404	− 65·0305	− 2·1471	− 34·6407	+ 35·5034	− 15·8181	+ 41·8175	+ 46·2653	+ 0·7135	+ 107·2394	− 53·4231	− 14·4715	− 39·7791	16·9860	+ 87·6020	+ 21·9138	+ 255·1079	83·5651	7·0238	+ 5·4110	+ 17·6774	+ 152·1985
+ 1940·16	+ 20·4469	− 11·7988	− 27·6312	+ 80·4974	+ 8·5564	− 8·6918	+ 74·3765	+ 14·0369	+ 88·2634	+ 18·7462	− 11·7952	− 40·7005	+ 107·3407	− 17·1124	55·3179	− 249·4938	− 27·3690	+ 13·1383	− 83·5651	+ 465·8073	− 41·5527	30·9668	+ 18·2472	+ 14·3237
+ 96·9	− 10·1648	+ 10·8090	+ 3·7562	+ 7·7196	+ 66·5285	− 61·5872	+ 20·4571	− 162·1764	+ 101·5733	− 28·5557	+ 98·5700	+ 16·4074	− 17·5259	+ 127·2024	+ 333·4931	− 11·3057	− 41·9859	+ 101·6024	− 7·0238	41·5527	+ 712·8179	+ 10·4879	180·8351	− 44·9890
744·62	+ 14·9021	+ 1·5337	+ 92·6496	− 28·2315	+ 17·5707	+ 21·6373	− 76·2811	+ 3·7876	− 41·8180	+ 86·6163	+ 0·4633	+ 150·0633	− 34·4533	+ 26·5715	+ 25·0846	+ 10·6602	+ 249·6279	− 7·8700	+ 50·4110	− 30·9668	+ 10·4879	+ 496·6484	2·8865	+ 103·3059
+ 677·74	− 11·4234	+ 29·5294	− 0·9272	− 5·7792	+ 66·6874	− 30·3242	+ 5·5452	+ 84·5546	− 246·4165	− 14·8216	+ 48·0652	+ 1·5021	+ 14·5636	+ 103·6081	− 107·3886	+ 36·1565	− 4·3294	+ 110·8758	+ 17·6774	+ 18·2472	180·8351	− 2·8865	+ 340·7320	+ 35·2622
+ 6859·50	− 42·2356	− 1·2964	+ 31·9533	− 44·4576	+ 9·9717	− 41·2272	− 16·2815	+ 331·0581	+ 128·1702	31·0540	+ 0·6839	+ 85·4451	− 83·6846	− 5·9906	− 113·1507	+ 132·7150	+ 87·6357	+ 18·3827	+ 152·1985	+ 14·3237	− 44·9890	+ 103·3059	+ 35·2622	+ 375·3137

$\Sigma(nn) = 91546·0.$

N.B. This table is corrected according to M. Erman's Note in Rep. Brit. Assoc. 1847, page 377.

Report relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850, *adopted by a Committee of the British Association at Swansea, August* 1848, *consisting of the following Members*:—Lord Wrottesley, Chairman, the Dean of Ely, Rev. Dr. Lloyd, *President of the Royal Irish Academy, and* Lieut.-Col. Sabine.

At the Cambridge meeting of the British Association, it was recommended that the Toronto Observatory should be continued on its then footing until the 31st of December 1848, unless in the mean time arrangements could be made for its permanent establishment.

The Observatory is built on ground lent by the Council of King's College at Toronto without charge, under the condition that when Government should discontinue the conduct of the Observatory, the building should be given over to the College, who would thereby have the option of continuing the observations should it appear desirable to do so.

The building of the University, in which some progress had been made, has been suspended until a bill shall have passed the Canadian Parliament by which the Board of Management will be determined; when there is reason to hope that the Observatory may be placed under the charge of the Professors of the College, and become a permanent establishment; to which desirable result Government may possibly contribute by making a transfer of the instruments as well as of the buildings.

The question to be now considered is therefore the expediency of recommending the continuance of the Observatory by Government for a year or two longer, until the affairs of the College shall be in a condition to enable the question of its permanent establishment to be brought before the authorities by whom the College shall hereafter be conducted.

The present state of the Observatory with regard to objects accomplished, and objects for the accomplishment of which provision is made, is as follows:—

Six years of hourly-observation were completed on the 30th June in the present year. This has been considered a sufficient duration for this laborious routine, and as furnishing a sufficient basis for the deduction of mean numerical values and mean *diurnal* variations of the magnetic and meteorological elements for every five days throughout the year. From the 1st of July 1848, therefore, night observation has ceased except at times of great magnetical and meteorological disturbance; and a reduction of one of the assistants has consequently been made. Observations are now made at convenient hours of the day, which compared with the mean values at the same hours in the corresponding periods of the six years, furnish, for the meteorological elements, the *non-periodic variations* which have become so important a feature in the extensive generalisations to which the science of meteorology has advanced; whilst for the magnetic elements they furnish a continuation of the differential results from which, assisted by monthly absolute determinations, the *secular* and *annual* variations, which necessarily require a longer series of observation than the *diurnal*, are in progress of elucidation. By the aid of equations furnished by the six years' hourly series, these objects can now be carried out by a system of observation which is comparatively extremely light; so much so as to be already within the compass of the College or other local direction. It does not however provide for the observation of disturbances, which require the continuous, or almost continuous observation of several instruments simultaneously.

For these, consequently, there is needed either a larger staff of assistants than it would be reasonable to expect in a permanent establishment, or a provision of efficient and proved self-recording instruments. Accordingly for some months past, and particularly since the termination of the hourly series, the attention of the Director has been turned to the introduction and practical trial of photographic instruments of this nature. From prudential reasons, one instrument only of each kind, one magnetical and one meteorological, has been thus fitted; but the success with these is such as appears fully to justify the application of similar apparatus to the other instruments. The chemical difficulties which might have been apprehended as obstacles to the employment of such instruments in a distant colony, appear to be surmounted, but experience is almost daily suggesting modifications and improvements, for which both apparatus and advice are required from home. In this respect therefore the Observatory cannot be said to be yet in the state in which it might be advantageously transferred to other hands; some short time longer is required for completing the equipment and comparing the performance of the self-recording instruments during disturbances with actual observations, for which latter a sufficient number of assistants is still retained.

There is no other observatory in America at which magnetic disturbances are recorded; and it is greatly to be desired that this record in a part of the globe so important in magnetic respects should not be wanting for the general comparison.

A few months' longer continuance in the present hands is also desirable for the purpose of bringing to a satisfactory conclusion the comparisons which have been instituted between the instruments by which the great body of observations have been made, and others which have been subsequently devised for attaining the same objects by other processes. There is reason to believe that the result of these comparisons will be in many cases highly satisfactory, in confirming the dependence which may be placed on the Toronto instruments and their results. The knowledge acquired by such comparisons is also likely to be very beneficial in guiding the selection of instruments hereafter for similar purposes in other colonies.

The cost of the Toronto Observatory with its present establishment (such as is proposed to be continued for a year or two longer) is £370 a-year, including a contingent of £100 for repairs and incidentals of all kinds. In this sum there is not included the *regimental* pay of the officer and non-commissioned officers, because they remain on the strength of the Artillery and are on the spot ready to serve in their military capacity should the public service require it. The observations which would be made during this additional period would not require to be printed as before *in detail*; and would form in substance a comparatively small appendix, which would have a place in the concluding volume of the Toronto observations.

NOTICES

AND

ABSTRACTS OF COMMUNICATIONS

TO THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

AT THE

SWANSEA MEETING, AUGUST 1848.

ADVERTISEMENT.

The Editors of the following Notices consider themselves responsible only for the fidelity with which the views of the Authors are abstracted.

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MATHEMATICS AND PHYSICS.

On the Mean Results of Observations. By the Rev. H. Lloyd, *D.D., M.R.I.A.*

It is well known that the mean value of any magnetical or meteorological element, for any day, may be had approximately, by taking the *arithmetical mean* of any number of observed values obtained at *equal intervals* throughout the twenty-four hours; the degree of approximation, of course, increasing with the number. It is important to ascertain the law which governs this approximation.

Any periodical function, u, of the variable v, being represented by the formula

$$u = a_0 + a_1 \sin (v + \alpha_1) + a_2 \sin (2 v + \alpha_2) + \text{\&c.},$$

in which a_0 is the true mean, or

$$a_0 = \frac{1}{2\pi} \int_{-\pi}^{\pi} u \, d v,$$

if u_1, u_2, u_3, &c., u_n, denote the values of the function u, corresponding to those of the variable

$$v, \quad v + \frac{2\pi}{n}, \quad v + \frac{4\pi}{n}, \ldots\ldots v + \frac{2(n-1)\pi}{n},$$

it may be shown that their arithmetical mean is equal to

$$a_0 + a_n \sin (n v + \alpha_n) + a_{2n} \sin (2 n v + \alpha_{2n}) + \text{\&c.},$$

whatever be the value of v. Hence, as the original series is always convergent, we have, when the number n is sufficiently great,

$$a_0 = \frac{1}{n} (u_1 + u_2 + u_3 + \text{\&c.} + u_n),$$

nearly; the limit of error being a_n, nearly. Hence, when the period in question is *a day*, we learn that the *daily mean value* of the observed element will be given by the mean of *two* equidistant observations, nearly, when a_2 and the higher coefficients are negligible; by the mean of *three*, when a_3 and the higher coefficients are negligible; and so on.

The coefficient a_3 is small in the case of the temperature; the curve which represents the course of the diurnal changes of temperature being, nearly, the curve of sines. In this case, then, the mean of the temperatures at any two *homonymous* hours is, nearly, the mean temperature of the day. This fact has been long known to meteorologists.

The coefficient a_3 is small in *all* the periodical functions with which we are concerned in magnetism and meteorology: and therefore the daily mean values of these functions will be given, very nearly, by the mean of any *three* equidistant observed values. The truth of this was shown by the author in the case of the magnetic declination, the atmospheric pressure, and temperature, as observed at the Magnetical Observatory of Dublin.

In choosing the particular hours for a continuous system of observations, we should select those which correspond nearly to the maxima and minima of the observed elements, so as to obtain also the *daily range*. This condition is fulfilled, in the

case of the magnetic declination, very nearly, by the hours 6 A.M., 2 P.M., 10 P.M.; which give, moreover, the maximum and minimum of temperature, and of the tension of vapour, nearly, and the maximum pressure of the gaseous atmosphere; and if we add the intermediate hours 10 A.M., 6 P.M., we shall have, nearly, the principal maxima and minima of the other two magnetical elements. The author accordingly proposes, as the best hours of observation in a limited system,

6 A.M., 10, 2 P.M., 6, 10.

The case is different where the course of the diurnal curve has been already obtained from a more extended system of observations. In this case the mean of the day may be inferred from observations taken at *any hours* whatever; and the hours of observation should therefore be chosen, chiefly, if not exclusively, with reference to the diurnal range of the observed elements.

The author proceeded, in the next place, to consider the course to be pursued in the reduction of a more extended system of observations (such as that prescribed by the Royal Society in 1839, and adopted by all the magnetical observatories), when some of the observations are deficient. He showed that, in this case, in deducing the daily means from the remaining observations, we must attend, not only to the elimination of the regular diurnal variation, but also to that of the irregular changes of longer periods, which are sometimes (as in the case of the atmospheric pressure) more influential in the result. With this view he determined the values of the *mean daily fluctuation* for each of the elements already referred to; and compared the mean values of the horary changes thence arising with that resulting from the regular diurnal variation.

The author showed, finally, in what manner the *monthly means* of the results obtained at any hour are to be corrected in the case of deficient observations, so as to render them comparable with those in which none are wanting; and he deduced the probable values of these corrections for each element, with the view of ascertaining in what cases the correction may be disregarded, and in what it is indispensable.

Account of Experiments belonging to a new Magnetic Action. *By* HERR PLÜCKER.

A crystal with one optical axis being brought between the two poles of a magnet, there will be a repulsive force going out from each of the poles and acting upon the optical axis. According to this action, the crystal, if suspended, will take such a position that its optical axis is placed within the equatorial plane. When the crystal has two optical axes there will be the same action on both, according to which the line bisecting the acute angle, formed by the axis, will turn into the equatorial plane. When the crystal is suspended in such a way that it may freely move round any line whatever of the plane containing both axes, this plane will take the equatorial position. Thus in a crystal which is neither transparent nor shows any trace of its crystalline structure, we may, by means of a magnet, find the optical axes: at the same time we get a new proof of the connexion between light and magnetism. When light is passing through a crystal, there are in general two directions where it is affected in a quite distinct way: these same directions are acted upon by a magnet.

On an Explanation of the "Beads" and "Threads" in Annular Eclipses. *By the* Rev. Prof. POWELL, *F.R.S.*

The principles on which this explanation is suggested are the following:—

1. The fact estabished by Mr. Airy, that the intensity of the sun's light increases rapidly from the extreme edge of the disc to some short distance inwards. [See Ast. Soc. Notices, vol. v. p. 216.]

2. The admitted law that *irradiation* increases with the intensity of the light.

On these grounds, when the irregularities of the moon's edge have their summits beyond the limb of the sun, but their depressions within it, so that they leave patches of light, these will be *enlarged* by irradiation, and will be *much more enlarged* as the depression is deeper within the sun's limb, where the light is so much more intense; they will thus appear elongated in a direction perpendicular to the limb, if actually

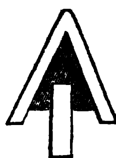
broad at the top and shallow. When the summits come within the limb, then, by the same causes, they will be melted down, or at least be reduced to their natural proportions. But the encroachment of the solar light on the dark disc will be greater towards the sides, where it is at a greater depth from the edge of the sun, and there will be thus a general protuberance towards the point of contact.

As to the cause of the diminution of the sun's light at the edge we are in entire ignorance. Again, dark glasses by diminishing the light may destroy the effect of irradiation, and the power and aperture of the telescope are known greatly to influence its amount. Hence it is quite conceivable that under different conditions the phænomena may be greatly modified, or may not appear at all.

On a new Case of Interference of Light. By the Rev. Prof. Powell, *F.R.S.*

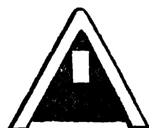
The principal experiment evincing this new kind of interference consists in placing a plate of glass or other transparent substance in a prismatic vessel containing a fluid (as *e.g.* oil of sassafras or anise with plate or crown-glass), so as to intercept the upper or thicker half of the prism, when the spectrum is seen covered with dark bands parallel to the edge of the prism, the number and breadth of which vary greatly with the refractive powers of the plate and medium, and with the thickness of the plate. For many combinations the plate must be inserted in the way just described, or towards *one* end of the spectrum, thus exhibiting an effect analogous to what was termed "polarity" in the experiments by partial interception of Sir D. Brewster: as in fig. 1. But for many combinations no bands are produced by this arrangement. In these cases however, on placing the plate to intercept the thinner part of the prism, as in fig. 2, bands will be produced.

Fig. 1.



This remarkable relation, as well as the number and character of the bands, can be all expressed by a formula derived from the simple interference theory; but for some more minute changes observed, recourse must be had to the diffraction theory, as in Mr. Airy's investigations (Phil. Trans. 1840, 1841). These investigations have been pursued by Mr. Stokes, of Pembroke College, Cambridge.

Fig. 2.



When plates of doubly refracting crystal are employed, two sets of bands are seen superimposed, even in those of the most feeble doubly refracting power, as quartz, &c. This may perhaps be serviceable to the mineralogist for detecting this property when very weak.

In general the number of bands observed in different cases agrees sufficiently well with calculation, and the method may be applied inversely for finding the refractive indices of one substance, the other being known. There is also a close analogy between these bands and those described by the Baron von Wrede, though produced in a totally different manner. [See Taylor's Scient. Mem. vol. i. pt. 3. p. 487.]

Observations of the Annular Eclipse of October 9, 1847. *Collected by the* Rev. Prof. Powell, *F.R.S.*

The British Association having at the last meeting printed and circulated "Suggestions for the Observation of the Annular Eclipse," a copy of which is also inserted in the last volume of its Reports (Sectional proceedings, p. 16), it has appeared desirable that at the present meeting a short statement should be laid before the members of the observations made, as far as intelligence has been received.

Unfortunately the morning was cloudy over nearly the whole of that part of England in which the eclipse was annular, so that numerous observers who might have been expected to respond to the invitation of the Association, had no results to communicate. On some parts of the east coast of Kent the eclipse was partially seen, but not (as far as has been ascertained) in the annular phase.

It being uncertain whether Greenwich would or would not fall within the limit of annularity, the Astronomer Royal, with the aid of several scientific friends,

equipped four stations to the north and three to the south of Greenwich, but the cloudy state of the weather rendered the preparations useless.

In communication with the Astronomer Royal of Great Britain, the astronomers of Italy made similar preparations at Padua, near the southern limit, but the weather was equally unpropitious. [See Astron. Soc. Annual Report, 1848; Notices, vol. viii. p. 79.]

In other parts of the world, however, several observations were made. The chief results, bearing on the physical inquiries referred to, are as follows:—

1. At Orleans (under the direction of the Bureau des Longitudes), MM. Mauvais and Goujon observed, as the cusps approached the ends extended more rapidly, but unequably and with a wriggling motion. Then one or two luminous points (beads) detached but melted into one again. Just before the completion of the annulus many such appeared, along the limb between the cusps, more or less *extended* but all very *thin*: they finally united. The ring did not exceed a few seconds in breadth. The dark intervals did *not* draw out into *threads*, but decreased *both in length and thickness*. (This is difficult to understand.) Upon the whole, they observe, the appearances were merely those of irregularities in the moon's edge, and not such as to require any supposition of *irradiation* or diffraction to account for them. [Ast. Soc. Notices, viii. 13.]

2. M. Schaub at Cilly in Styria observed the eclipse with a telescope having a power of 40 and a red glass, and saw the annulus formed *without any irregularity*. He then applied a power of 60 and a compound glass of complementary colours, giving a white image, and noticed the lunar mountains projected on the sun's disc; the limb undulated, but continued circular up to the second contact, which was *a contact with the tops of the mountains first, leaving bright intervals*, but without distortion. [Ibid. p. 13.]

3. Capt. Jacob, at Bombay, with a 3½ feet Dollond, power 40, saw just before the formation of the annulus a faint light outside the cusp. At the south cusp a break as if from a projection on the moon's limb, which increased to about 1′ in breadth, attaching the limbs; then elongated and suddenly broke, the ends being jagged. At the termination of the annulus a portion of 30° on the limb was suddenly occupied by beads, too many to count, but which lasted only two seconds. No light was seen about the moon off the sun. [Ibid. p. 27.]

4. Major Lysaght, at Hingolee, with 3½ Dollond, power 25, and glass giving a greenish-yellow image, saw near contact the limb undulating, the edge "hillocky," which appearance subsided, till just at contact a dark band from one "hillock" connected the limbs, followed by another: the mode of its disappearance was not noticed. As the ring increased in breadth the limb of the moon became "pinnacled," and a blaze of light appeared on it. (This part of the description is very obscure.) Then the limb became smooth again, except one hillock, which elongated and formed a connecting band, as at first, and then broke in two. (This circumstance seems extraordinary, but is not further explained.) [Ibid. p. 130.]

5. Dr. Forster, at Bruges (in a letter to Prof. Powell), states that he observed a very remarkable luminous arc or ridge of light, differently coloured from the rest of the sun, extending along and immediately on the limb of the moon between the cusps. It lasted nearly five minutes. He considers it as unlike any appearance described before, and remarks that it appeared *as if* produced by a lunar atmosphere refracting the light of the sun; but the rapid transit of flying clouds prevented any very accurate observations. It was seen with a telescope of low power. Perhaps this was the same with the blaze of light described by Major Lysaght.

On those Variations of the Force and the Direction of the Terrestrial Magnetism which seem to depend on the Aurora Borealis. By Dr. SILJESTRÖM.

The author stated, from observations made in Finmarken, at about 70° north latitude, that in the course of an aurora borealis there are two magnetical periods to be discerned, in both of which the disturbances are going on in a quite opposite way, so as to increase and decrease successively the different magnetical elements. He stated also that the simultaneous variations of these elements, with few excep-

tional cases, are following that simple law, that while the intensity and the western declination increase, the inclination decreases. In respect to the variations of the luminous phænomenon itself, he had only been able to ascertain that during the first of the above periods the aurora borealis was in general exclusively seen in the northern part of the heaven, while during the second period it extended itself more to the south, so that the magnetical variations before mentioned seem to be accompanied by a translation of the light from north to south.

On a Difficulty in the Theory of Light. By G. G. STOKES, *M.A.*

The distinction between common light and elliptically polarized light is fully accounted for, on the undulatory theory, by the very natural supposition that in common light the mode of vibration changes a great many times in the course of one second; so that even in a very small fraction of a second there is, on the average, as much light polarized in one way as there is light polarized in the opposite way. So unlikely does it seem that this should not be the case, when we consider the enormous number of vibrations which take place in one second, that, as the author contended, it would be a most serious difficulty in the way of the undulatory theory if common light exhibited the rings in crystals, or any of the peculiar phænomena exhibited by elliptically polarized light. It had however been thought necessary, in order to account for the phænomena, to suppose that the mode of vibration passed *abruptly* from one thing to the other. This abruptness of transition was the "difficulty" alluded to in the title; and the author contended that there was no occasion to suppose any such abruptness to exist. In fact, the apparent necessity for the supposition of an abrupt transition appears to have arisen from finding that common light could not be represented by supposing the particles to move in ellipses the major axes of which slowly revolve. But such a mode of vibration results from the superposition of two series of vibrations, of nearly equal length of wave but of unequal intensity, belonging respectively to right-handed and to left-handed circularly polarized light. Hence such a mode of vibration is not a fair representation of common light, the very notion of which implies that it contains as much of any one kind of polarized light as of the opposite.

On the Refraction of Light beyond the Critical Angle. By G. G. STOKES, *M.A.*

The principal object of the author in this communication was to give an expression, obtained from the undulatory theory of light, for the intensity of the central spot of Newton's rings, when the angle of incidence exceeds the critical angle. It has been shown by those who have treated the subject of reflexion and refraction dynamically, that when the angle of incidence exceeds the critical angle, the expression for the disturbance in the second medium contains an exponential, involving the co-ordinate perpendicular to the surface, so that the disturbance is insensible at a distance from the surface of a small multiple of λ the length of a wave. The expressions for this superficial disturbance have not, however, so far as the author is aware, been hitherto applied to the explanation of any phænomenon, although the existence of the central spot in Newton's rings beyond the critical angle has been unhesitatingly attributed to this cause by Dr. Lloyd, in his Report on Physical Optics. The author has not entered into any particular dynamical theory, but has preferred deducing his results from Fresnel's expressions for the intensity of reflected and refracted polarized light, which, except perhaps in the case of very highly refracting substances, are at least a very near approximation to the truth. The method employed does not even render it necessary to enter into the question, whether the vibrations of plane polarized light are in or perpendicular to the plane of polarization. When the angle of incidence exceeds the critical angle, Fresnel's expressions become imaginary; and by reasoning similar to that employed by Mr. O'Brien in interpreting those expressions in the case of reflected light, the author has arrived at the following simple rule, which embraces all cases.

Let x be measured along the reflecting surface, y perpendicular to that sur-

face, and directed into the first medium, both being measured parallel to the plane of incidence; and let the expression for the vibration be put under the form $a \sin \frac{2\pi}{\lambda}(\sin i \,.\, x + \cos i \,.\, y + v\,t)$, $b \sin \frac{2\pi}{\lambda}(\sin i \,.\, x - \cos i \,.\, y + v\,t)$, or

$$c \sin \frac{2\pi}{\lambda}\left(\frac{v}{v'}[\sin i' \,.\, x + \cos i' \,.\, y] + v\,t\right),$$

according as the incident, reflected or refracted vibration is considered. Whenever the coefficient of vibration becomes imaginary, put it under the form $\varrho\,\varepsilon^{\theta\sqrt{-1}}$, retain the modulus ϱ for the coefficient, and subtract θ from the phase. Whenever the coefficient of y under the circular function becomes imaginary, and equal to $\pm\, k\sqrt{-1}$, remove y from the circular function and multiply by the exponential $\varepsilon^{\pm k y}$.

This rule having been established, the calculation of the intensity presents no difficulty. If I be the intensity of the reflected light, that of the incident light being unity, it is found that

$$I = \frac{(1-q)^2}{(1-q)^2 + 4\,q \sin^2 2\,\theta}.$$

In this expression it is supposed that the two media between which the spot is formed are of the same kind, and that the incident light is polarized, either in the plane of incidence, or in a plane perpendicular to the plane of incidence: q is the same in the two cases, being equal to $\varepsilon^{-\frac{4\pi T}{\lambda}\sqrt{\mu^2 \sin^2 i - 1}}$, where T is the thickness of the plate of air at the point considered; but θ is different, being equal to θ_1 in the former case, and θ_2 in the latter, where

$$\tan \theta_1 = \frac{1}{\mu} \tan \theta_2 = \sec i \sqrt{\mu^2 \sin^2 i - 1}.$$

When the vibrations take place in the plane of incidence, it would be necessary to consider separately the resolved parts of the vibration parallel to x and parallel to y; but the same expression would have been obtained for I if this consideration had been neglected. It is unnecessary to write down the expression for the intensity of the transmitted light, since the sum of the two intensities is equal to unity. For this reason it will be sufficient to discuss the intensity of the reflected light.

From the expression for I the author has deduced the following consequences:

1. At the point of contact $T = 0$; and on receding from that point T varies as r^2, r being the radius vector measured from the point of contact. Hence at the point of contact there is absolute darkness; on receding from that point the intensity increases, at first very slowly, varying ultimately as r^4, so that for some distance round the centre the darkness is as to sense perfect; then the intensity increases more rapidly, and then it very rapidly approaches its limiting value 1. This agrees with observation.

2. For different colours, the same fraction of the incident light is reflected at points for which r varies as $\sqrt{\lambda}$. Hence the spot is larger for red light than for violet; but the separation of colours is small. This agrees with observation.

3. When the angle of incidence lies between the critical angle and the angle $\sin^{-1}\left(\frac{2}{1+\mu^2}\right)^{\frac{1}{2}}$, the spot is larger for light polarized in a plane perpendicular to the plane of incidence than for light polarized in the plane of incidence; while between the latter angle and 90° the reverse is the case. This difference of size agrees with observation, but it is impossible to say at what angle the change takes place.

4. Suppose the internally incident light polarized at an azimuth of 45°, or thereabouts; and let the transmitted light be analysed so as to darken the centre of the spot; then a faint ring of light ought to be seen separating the dark centre from the generally dark field of view. This ring ought to be slightly bluish inside and reddish or brownish outside. The author has not tried this experiment.

On the Perfect Blackness of the Centre of Newton's Rings.
By G. G. STOKES, *M.A.*

The absence of all reflected light at the centre of Newton's rings, when formed between two lenses of the same substance, was explained long ago by Fresnel, by the aid of a law discovered experimentally by M. Arago, that light is reflected in the same proportion at the first and second surfaces of a transparent plate bounded by parallel surfaces. It occurred to the author that this law might be obtained very simply from theory, by means of what may be called the *principle of reversion*. By this is meant the general dynamical principle, that if in any material system, in which the forces depend only on the positions of the particles, the velocity of each particle be suddenly reversed, the previous motion will be repeated in the reverse direction. It follows from this principle, that in the case of a series of waves of light incident on the surface of an ordinary medium, and producing a series of reflected, and a series of refracted waves, if the vibrations in the reflected and refracted series be reversed, the incident series will be produced, only in a reverse direction. But the reflected and refracted series, when reversed, would each produce a series of reflected, and a series of refracted waves; and it follows from the principle of superposition, that, of these four series, the two which are situated within the medium must neutralize each other, and the two which are situated outside of the medium must together produce the incident series reversed. Two equations are thus obtained, whereby the perfect blackness of the centre of Newton's rings is explained. These equations are those which are written in Airy's Tract $b = -e$, $cf = 1 - e^2$. The detail of this method will soon appear in the Cambridge and Dublin Mathematical Journal.

On the Resistance of the Air to Pendulums. *By* G. G. STOKES, *M.A.*

There are a few cases in which the resistance of a fluid to a pendulum oscillating in it have been calculated on the common theory of hydrodynamics, in which the pressure is supposed equal in all directions. The results in the cases of a sphere and of a long cylindrical rod are very simple, and may be expressed by saying that the mass of the pendulum must be conceived to be increased in the former case by the half, and in the latter by the whole of the fluid displaced; this additional mass increasing the inertia of the pendulum without increasing its weight. These results agree very nearly with Dubuat's experiments on spheres oscillating in air, Dubuat having employed spheres of large diameter, and with Baily's experiments on cylindrical tubes of 1½ inch diameter. With smaller spheres and thinner rods, however, the results no longer agree with experiment, as appears from the experiments of Bessel and Baily, the discrepancy being so much the greater as the diameter of the sphere or rod is the smaller. The author stated that he had solved the problem in the cases of a sphere and of a cylindrical rod, using instead of the common equations of hydrodynamics the equations which he had given in the 8th volume of the Cambridge Philosophical Transactions, and which had been previously obtained, by different methods, by Navier, by Poisson, and by M. de Saint-Venant. The result in the case of the sphere is very simple, although the function which expresses the state of motion of each particle of the fluid is rather complicated. It appears that the effect on the time of oscillation will be obtained by conceiving a mass equal to $\left(\frac{1}{2} + \frac{9}{4}s\right)m$ to be added to the mass of the sphere, m being the mass of fluid displaced, and $s = \frac{1}{a}\sqrt{\frac{2\mu t}{\pi \rho}}$, a being the radius of the sphere, t the time of oscillation, ρ the density, and μ the constant so denoted in the author's paper referred to above. This constant must be determined by experiment for each fluid in particular, and even for the same fluid at different temperatures, since it probably decreases as the temperature increases. Besides the effect on the time of oscillation, the arc of oscillation slowly decreases, the expression for the decrement of the arc involving the quantity $\frac{9}{4}s(1 + s)m$.

The result in the case of the cylinder is much more complicated, and requires the numerical calculation of functions belonging to this particular problem. The author

has expressed the effect on the time and arc of oscillation by means of ascending series, which are always convergent. The result involves the remarkable transcendent $\Gamma'\left(\frac{1}{2}\right)$, $\Gamma'(n)$ being the derivative of $\Gamma(n)$. The author has also obtained a descending series, which is much more convenient for numerical calculation when the diameter of the cylinder is large. It appears from theory that the factor which Baily has denoted by n increases indefinitely as the radius of the cylinder decreases: the mass of air which must be conceived to be dragged by the cylinder decreases, but very slowly, varying ultimately as the square of the reciprocal of the logarithm of a quantity which varies as the time of oscillation divided by the square of the radius of the cylinder.

The diameters of the cylindrical rods employed by Baily were ·410, ·185 and ·072 inch; and the corresponding values of n, which according to the common theory of hydrodynamics ought to be equal to 2, were 2·932, 4·083, and 7·530. Each of these results furnishes an equation for the determination of μ, or rather of $\sqrt{\frac{\mu}{-}}$, which is what enters into the calculation; and the three results concurred in giving to the latter quantity a value lying between ·11 and ·12, an inch and a second being the units of space and time. The value ·11 satisfied very nearly the experiments on spheres suspended by fine wires; the effect of the wire, which on this theory is not quite insensible, being taken into account, and a small correction, estimated at half the correction calculated for a spherical envelope of the same radius, being made for the finite size of the hollow cylinder within which the spheres were swung.

On the Equilibrium of Magnetic or Diamagnetic Bodies of any Form, under the Influence of the Terrestrial Magnetic Force. By Prof. W. THOMSON.

If a body composed of a magnetic substance, such as soft iron, or of a diamagnetic substance, be supported by its centre of gravity, the effects of the terrestrial magnetic force in producing magnetism by induction, and in acting on the magnetism so developed, are in general such as to impress a certain directive tendency on the mass. The investigation of these circumstances leads to results according to which the conditions of equilibrium of a body of any irregular form may be expressed in a very elegant and simple manner.

In the present communication I shall merely give a brief general explanation of the conclusions at which I have arrived, without attempting to state fully the process of reasoning on which they are founded, as this could not be rendered intelligible without entering upon mathematical details, which must be reserved for a paper of greater length.

In the first place, if the body considered be an ellipsoid of homogeneous matter, supported by its centre of gravity, it is clear that it will be in equilibrium with any one of its three principal axes in the direction of the lines of force; and if it be put into any other position, the action of the earth upon it will be a couple, of which the moment may be expressed very simply in terms of the quantities denoting the position of the axes with reference to the direction of the terrestrial force, and certain constant magnetic elements depending on the substance and dimensions of the body.

In considering the corresponding problem for a body of any irregular form, we readily obtain for the components of the directive couple, round three rectangular axes chosen arbitrarily in the body, expressions involving nine constant magnetic elements. I have succeeded in proving that six of these elements must be equal, two and two; so that the entire number of independent constants is reduced to six. I have thus arrived at the interesting theorem, that there are, in any irregular body, *three principal magnetic axes at right angles to one another*, such that if the body be supported by its centre of gravity, it will be in equilibrium with any one of these axes in the direction of the terrestrial magnetic force. If the body be held in any other position, there will be a directive couple of which the moment is expressible in precisely the same form as in the case of an ellipsoid, in terms of the magnetic elements of the body, and of the quantities denoting its position.

From this it follows, that, as far as regards the directive action of terrestrial magnetism, *the ellipsoid with three unequal axes may be taken as the general type for a body of any form whatever.*

Besides other special cases of interest, to which it is unnecessary for me at present to call attention, on account of the close analogy which is presented by the well-known theory of principal axes in dynamics, there is one to which I shall allude, on account of its importance with reference to the general principles on which the directive agency depends. If the body considered be a cube, the three principal magnetic elements will be equal, and therefore the corresponding ellipsoid must have its three axes equal; that is, it must be a sphere. Hence a cube supported by its centre of gravity cannot experience any directive tendency, and will therefore be *astatic.*

Now a mass of any form may be divided into an infinite number of small cubes, and the resultant of the actual directive couples on all of these cubes will determine the directive tendency of the whole mass. Hence if each small cube were acted upon only by the terrestrial magnetic force, there would be no directive agency on the body; and it is to the modification of the circumstances introduced by the mutual action of the different parts of the body that we must ascribe the directive tendency which is actually experienced, in general by irregular, but especially by elongated masses. This modification is distinctly alluded to by Mr. Faraday in his memoir on the General Magnetic Condition of Matter (Experimental Researches, § 2264), and the directive tendency which he has observed in needles of diamagnetic substances is shown to depend on essentially different physical circumstances (§§ 2269, 2418) connected with the variation of the total intensity of the resultant magnetic force in the neighbourhood of the poles of a magnet, and quite independent of the actual directions of the lines of force. A mathematical investigation of the circumstances on which these phænomena depend will be found in the Cambridge and Dublin Mathematical Journal (May 1847).

From the principles alluded to above, we may draw the following general conclusions with reference to the action experienced by a body subjected to magnetic influence when the intensity of the magnetizing force is constant in its neighbourhood.

1. The directive tendency on a diamagnetic substance of any form must be extremely small, probably quite insensible in any actual experiment that can be made; depending as it does upon the mutual action of the parts of the body which are primarily influenced to but a very feeble extent in the case of every known diamagnetic.

2. An elongated body, whether of a magnetic or of a diamagnetic substance, will tend to place itself in the direction of the lines of force; so that, for instance, either a bar of soft iron, or a diamagnetic bar, supported by its centre of gravity, would, if perfectly free, assume the position of the dipping-needle.

On the Theory of Electro-magnetic Induction. By Prof. W. Thomson.

The theory of electro-magnetic induction, founded on the elementary experiments of Faraday and Lenz, has been subjected to mathematical analysis by Neumann, who has recently laid some very valuable researches on this subject before the Berlin Academy of Sciences. The case of a closed linear conductor (a bent metallic wire with its ends joined) under the influence of a magnet in a state of relative motion is considered in Neumann's first memoir*, and a very beautiful theorem is demonstrated, completely expressing the circumstances which determine the intensity of the induced current. It has appeared to me that a very simple *à priori* demonstration of this theorem may be founded on the axiom that the amount of work expended in producing the relative motion on which the electro-magnetic induction depends must be equivalent to the mechanical effect lost by the current induced in the wire.

In the first place, it may be proved that the amount of the mechanical effect continually *lost* or spent in some physical agency (according to Joule the generation of heat) during the existence of a galvanic current in a given closed wire is, for a

* A translation of this memoir into French is published in the last April number of Liouville's *Journal des Mathématiques.*

given time, proportional to the square of the intensity of the current. For, whatever be the actual source of the galvanism, an equivalent current might be produced by the motion of a magnetic body in the neighbourhood of the closed wire. If now, other circumstances remaining the same, the intensity of the magnetism in the influencing body be altered in any ratio, the intensity of the induced current must be proportionately changed; hence the amount of work spent in the motion, as it depends on the mutual influence of the magnet and the induced current, is altered in the duplicate ratio of that in which the current is altered; and therefore the amount of mechanical effect lost in the wire, being equivalent to the work spent in the motion, must be proportional to the square of the intensity of the current. Hence if i denote the intensity of a current existing in a closed conductor, the amount of work lost by its existence for an interval of time dt, so small that the intensity of the current remains sensibly constant during it, will be $k \cdot i^2 \cdot dt$; where k is a certain constant depending on the resistance of the complete wire.

Let us now suppose this current to be actually produced by induction in the wire, under the influence of a magnetic body in a state of relative motion. The entire mutual force between the magnetic and the galvanic wire may, according to Ampère's theory, be expressed by means of the differential coefficients of a certain "force function." This function, which may be denoted by U, will be a quantity depending solely on the form and position of the wire at any instant, and on the magnetism of the influencing body. During the very small time dt, let U change from U to $U+dU$, by the relative motion which takes place during that interval. Then $i\,dU$ will be the amount of work spent in sustaining the motion; but the mechanical effect lost in the wire during the same interval is equal to $k\,i^2\,dt$; and therefore we must have

$$i\,dU=k\,i^2\,dt.$$

Hence, dividing both members by $k\,i\,dt$, we deduce

$$i=\frac{1}{k}\cdot\frac{dU}{dt},$$

which expresses the theorem of Neumann, the subject of the present communication. We may enunciate the result in general language thus:—

When a current is induced in a closed wire by a magnet in relative motion, the intensity of the current produced is proportional to the actual rate of variation of the "force function" by the differential coefficients of which the mutual action between the magnet and the wire would be represented if the intensity of the current in the wire were unity.

On a means of determining the apparent Solar Time by the Diurnal Changes of the Plane of Polarization at the North Pole of the Sky. By Professor WHEATSTONE, *F.R.S.*

"A short time after the important discovery by Malus of the polarization of light by reflexion, it was ascertained by Arago that the light reflected from different parts of the sky was polarized. The observation was made in clear weather with the aid of a thin film of mica and a prism of Iceland spar; he saw that the two images projected on the sky were in general of dissimilar colours, which appeared to vary in intensity with the hour of the day and with the position, in relation to the sun, of the part of the sky from which the rays fell upon the film. The first attempt to assign a law to the phænomena of atmospheric polarization was made by Professor Quetelet of Brussels in 1825 in the following terms:—'If the observer consider himself as placed in the centre of a sphere of which the sun occupies one of the poles the polarization is at its maximum at the different points of the equator of this sphere, and goes on diminishing in the ratio of the squares of the sines unto the poles where it is at zero.' This law would be true did the reflected light proceeding from the part of the sky regarded arise solely from the direct light of the sun sent to that part; but other secondary reflexions occur which complicate the result and give rise to the neutral points since discovered by Arago, Babinet and Brewster. But for the purpose of explaining the principle of the instrument now submitted to the examination of the Section, we need not take into consideration the intensity of the polar-

ization of the part of the sky to which it is directed; the plane of polarization for the time being is the only thing we need concern ourselves about, and a very simple expression, stated first I believe by M. Babinet, defines the position of this plane for any given point of the sky; it is this: 'For a given point of the atmosphere the plane of polarization of the portion of polarized light which it sends to the eye coincides with the plane which passes through this point, the eye of the observer and the sun.' The truth of this law may be easily demonstrated without any refined apparatus in the following manner:—Let the observer be provided with a Nicol's prism and a plate of Iceland spar cut perpendicularly to the axis, and stand with his back towards the sun; keeping the diagonal of the prism always in the same vertical plane, let him direct it successively to every point of the sky within that plane; the intensity of the polarization indicated by the brightness of the coloured image will vary very considerably at these different points, but the plane of polarization indicated by the upright position of the black or white cross, as the case may be, will remain unchanged. I leave out of consideration for the present the inversion of the plane of polarization observed occasionally near the horizon below the neutral point.

"If we direct our analysing apparatus to the zenith during the whole day, the change in the plane of polarization of that point of the sky will correspond with the azimuths of the sun. Let us now turn our attention to the north pole of the sky: as the sun in its apparent daily course moves equably in a circle round this pole, it is obvious that the planes of polarization at the point in question change exactly as the position of the hour-circles do. The position of the plane of polarization of the north pole of the sky will at any period of the day therefore indicate the apparent or true solar time. The point of intersection of the hour-circles, or the north pole of the sky, corresponds on only two days of the year with the maximum intensity of polarization; these days are the equinoxes; on all other days the points of maximum polarization of the respective hour-circles describe a circle round the point of intersection; but the angular distance thereof, which is greatest at the solstices, never exceeding 23° 28′, the polarization has always sufficient intensity to exhibit brilliant colours in films of selenite, &c.

"These points being premised, I proceed to describe the new instrument, which I have called the Polar Clock or Dial. It is thus constructed. At the extremity of a vertical pillar is fixed, within a brass ring, a glass disc, so inclined that its plane is perpendicular to the polar axis of the earth. On the lower half of this disc is a graduated semicircle divided into twelve parts (each of which is again subdivided into five or ten parts), and against the divisions the hours of the day are marked, commencing and terminating with VI. Within the fixed brass ring containing the glass dial-plate, the broad end of a conical tube is so fitted that it freely moves round its own axis; this broad end is closed by another glass disc, in the centre of which is a small star or other figure, formed of thin films of selenite, exhibiting when examined with polarized light strongly contrasting colours; and a hand is painted in such a position as to be a prolongation of one of the principal sections of the crystalline films. At the smaller end of the conical tube a Nicol's prism is fixed so that either of its diagonals shall be 45° from the principal section of the selenite films. The instrument being so fixed that the axis of the conical tube shall coincide with the polar axis of the earth, and the eye of the observer being placed to the Nicol's prism, it will be remarked that the selenite star will in general be richly coloured, but as the tube is turned on its axis the colours will vary in intensity, and in two positions will entirely disappear. In one of these positions a small circular disc in the centre of the star will be a certain colour (red for instance), while in the other position it will exhibit the complementary colour. This effect is obtained by placing the principal section of the small central disc 22½° from that of the other films of selenite which form the star. The rule to ascertain the time by this instrument is as follows: the tube must be turned round by the hand of the observer until the coloured star entirely disappears while the disc in the centre remains red; the hand will then point accurately to the hour. The accuracy with which the solar time may be indicated by this means will depend on the exactness with which the plane of polarization can be determined; one degree of change in the plane corresponds with four minutes of solar time.

"The instrument may be furnished with a graduated quadrant for the purpose of adapting it to any latitude; but if it be intended to be fixed in any locality, it may be permanently adjusted to the proper polar elevation and the expense of the graduated quadrant be saved: a spirit-level will be useful to adjust it accurately. The instrument might be set to its proper azimuth by the sun's shadow at noon, or by means of a declination needle; but an observation with the instrument itself may be more readily employed for this purpose. Ascertain the true solar time by means of a good watch and a time equation table, set the hand of the polar clock to correspond thereto, and turn the vertical pillar on its axis until the colours of the selenite star entirely disappear. The instrument then will be properly adjusted.

"The advantages a polar clock possesses over a sun-dial are,—1st. The polar clock being constantly directed to the same point of the sky, there is no locality in which it cannot be employed, whereas, in order that the indications of a sun-dial should be observed during the whole day, no obstacle must exist at any time between the dial and the places of the sun, and it therefore cannot be applied in any confined situation. The polar clock is consequently applicable in places where a sun-dial would be of no avail; on the north side of a mountain or of a lofty building for instance. 2ndly. It will continue to indicate the time after sunset and before sunrise; in fact, so long as any portion of the rays of the sun are reflected from the atmosphere. 3rdly. It will also indicate the time, but with less accuracy, when the sky is overcast, if the clouds do not exceed a certain density.

"The plane of polarization of the north pole of the sky moves in the opposite direction to that of the hand of a watch; it is more convenient therefore to have the hours graduated on the lower semicircle, for the figures will then be read in their direct order, whereas they would be read backwards on an upper semicircle. In the southern hemisphere the upper semicircle should be employed, for the plane of polarization of the south pole of the sky changes in the *same* direction as the hand of a watch. If both the upper and lower semicircles be graduated, the same instrument will serve equally for both hemispheres."

Several other forms of the polar clock were then described; the following is a description of one among them, which, though much less accurate in its indications than the preceding, beautifully illustrates the principle.

On a plate of glass twenty-five films of selenite of equal thickness are arranged at equal distances radially in a semicircle; they are placed so that the line bisecting the principal sections of the films shall correspond with the radii respectively, and figures corresponding to the hours are painted above each film in regular order. This plate of glass is fixed in a frame so that its plane is inclined to the horizon 38° 32′, the complement of the polar elevation; the light passing perpendicularly through this plate falls at the polarizing angle 56° 45′ on a reflector of black glass, which is inclined 18° 13′ to the horizon. This apparatus being properly adjusted, that is so that the glass dial-plate shall be perpendicular to the polar axis of the earth, the following will be the effects when presented towards an unclouded sky. At all times of the day the radii will appear of various shades of two complementary colours, which we will assume to be red and green, and the hour is indicated by the figure placed opposite the radius which contains the most red; the half-hour is indicated by the equality of two adjacent tints.

On rendering the Electric Telegraph subservient to Meteorological Research. By JOHN BALL, *M.R.I.A.*

What is popularly termed the weather is a general expression for the physical condition of the atmosphere with reference to heat, pressure, moisture, and the velocity and direction of its motion. Two classes of causes determine these conditions at any given point of the earth's surface. The first class may for short periods of time be considered as constants, depending on the position of the point of observation on the globe and the physical conformation of the adjoining district. The second class, upon which the proverbial uncertainty of the weather depends, arise from the influence exerted by each portion of the atmosphere upon those surrounding it, by virtue of which a disturbance of equilibrium at any one point is rapidly propagated in all directions. In common language this is expressed by saying that

the direction of the wind is at once the cause and the indication of changes of the weather. However far we may be from a general solution of the problem of atmospheric disturbances, meteorologists have made considerable progress in tracing the connection between successive states of the weather, owing to the mutual influence of contiguous portions of the atmosphere. These cases have been studied *à posteriori*, comparing the known results with observations extending over considerable areas. Now that we have the means of receiving information in an indefinitely short space of time by the Electric Telegraph, these problems, under favourable circumstances, may be studied *à priori*. In London we may receive instantaneous intelligence of the condition of the atmosphère, as to the five above-mentioned elements, from nearly all the extremities of Great Britain. With a delay of about four hours we can have similar intelligence from the western part of Ireland, and with a still shorter delay our communications may extend to the centre of France, the banks of the Rhine, and even to the frontiers of Hungary and Poland.

I do not pretend to say that with such elements for calculation we should at once be enabled to predict changes in the weather with absolute certainty. It would require some time to eliminate the action of accidental and local causes at particular stations; but there is no reason to doubt that in a short time the determinations thus arrived at would possess a high degree of probability. The ordinary rate at which atmospheric disturbances are propagated does not seem to exceed twenty miles per hour; so that with a circle of stations extending about 500 miles in each direction, we should in almost all cases be enabled to calculate on the state of the weather for twenty-four hours in advance.

Description of a New Instrument for observing the Apparent Positions of Meteors. By the Rev. J. Challis, *M.A., F.R.S., Plumian Professor of Astronomy at the University of Cambridge (in a Letter to the Assistant General Secretary).*

Having had occasion to make use of observations of auroral arches and coronæ, and other meteoric phænomena, I have seen the desirableness of noting the positions by instrumental means, rather than trusting to vague estimation and reference to stars. Accordingly I have had a brass instrument constructed for me by Mr. Simms, Fleet Street, London, which may possibly answer this purpose in some degree. I propose to call it a *Meteoroscope*. It is in principle an altitude and azimuth instrument, in the form of a theodolite, having a horizontal circle graduated from 0° to 360°, and a vertical arc graduated from 0° to 120°, each about 4 inches in radius. The vertical arc is readily moveable about a vertical axis passing through the centre of the horizontal circle, and instead of having a telescope, which would be inapplicable to the class of observations proposed to be taken, it carries a bar 18 inches long, having a small rectangular plate at each end. One of these plates is perforated by a circular hole one-sixth of an inch in diameter, through which the object is viewed, and the other has its edges vertical and horizontal, the observation of altitude being made by bringing the horizontal edge, and the observation of azimuth by bringing the vertical edge, to bisect the object. Both observations are made at the same time by placing the angular point in apparent coincidence with the object. The eyelet-hole should not be less than the pupil of the eye when dilated, that there may be as little loss of light as possible. No parallax of serious amount will arise from the size of the hole, as it is always easy to judge when the centre of the pupil and that of the hole are nearly coincident. The bar is moveable about a horizontal axis passing through the centre, and perpendicular to the plane of the vertical arc, and is carried by a radius so that the direction of its length is a tangent to the arc. The direction of the radius is somewhat oblique to that of the bar, in order that the line of collimation may pass the zenith about 20° when the radius is brought to a horizontal position. For the same reason the centre of motion of the bar is elevated about an inch and a half above the plane of the azimuth circle. For the purpose of viewing conveniently an object near the zenith, the plate at the eye-end of the bar has a small silvered glass reflector inclined at an angle of 45° to the plane of the plate, and adjustible by a screw. The object is seen by reflexion in a direction perpendicular to the line of collimation, through another

eyelet-hole made in a small plate attached for this purpose. The reflector is properly adjusted when a star is seen in coincidence with the left-hand angular point of the plate at the opposite end of the bar, at the same time that it is seen by direct vision through the other eyelet-hole in coincidence with the right-hand angular point. There are two clamps, one for clamping the bar to the vertical arc, and the other for clamping the vertical arc to the azimuthal circle. The latter may be held by the right-hand to give the azimuthal movement, and at the same time to be in readiness to clamp, while the bar is held by the left-hand for aiming. When the bar is not clamped to the vertical arc, it is prevented slipping partly by a spring and partly by a counterpoise. There are verniers to read off azimuths and altitudes to single minutes, and the vertical arc carries a small spirit-level for the horizontal adjustment. The instrument has a tripod support, with three screws for adjusting horizontally, and when in use is placed on a wooden stand, to the upper surface of which are fastened three brass Ys. The feet of the screws are placed in these Ys, and thus the instrument is put expeditiously in a given position. When not in use, it is kept under cover near the stand.

On very dark nights the edges of the plate at the object-end of the bar were seen with difficulty. To remedy this inconvenience the face of the plate turned towards the eye was painted white, after which the light from a lamp at a considerable distance made it sufficiently visible. In general the luminosity of the sky makes the plate appear dark on a light ground.

It is proposed to employ the meteoroscope in measuring the positions of arches and coronæ of the Aurora Borealis, the dimensions and position at different times of the year of the Zodiacal Light, and the points of first appearance and disappearance of meteors and shooting stars. Several of these observations, to be of any value, require to be made simultaneously at different localities, and with the same degree of precision. It seems to me surprising that meteorologists have not hitherto provided themselves with instruments like that I have been describing; many observations of meteors having been comparatively useless on account of want of accuracy. I consider that with care the altitude of a star may be measured by this instrument with a probable error of two minutes, and that it is abundantly accurate for the purposes to which it is proposed to apply it. In any case in which it is employed it is advisable to take the altitude and azimuth of a known star at a noted time near the place of the meteor, in order to eliminate index errors and errors of adjustment.

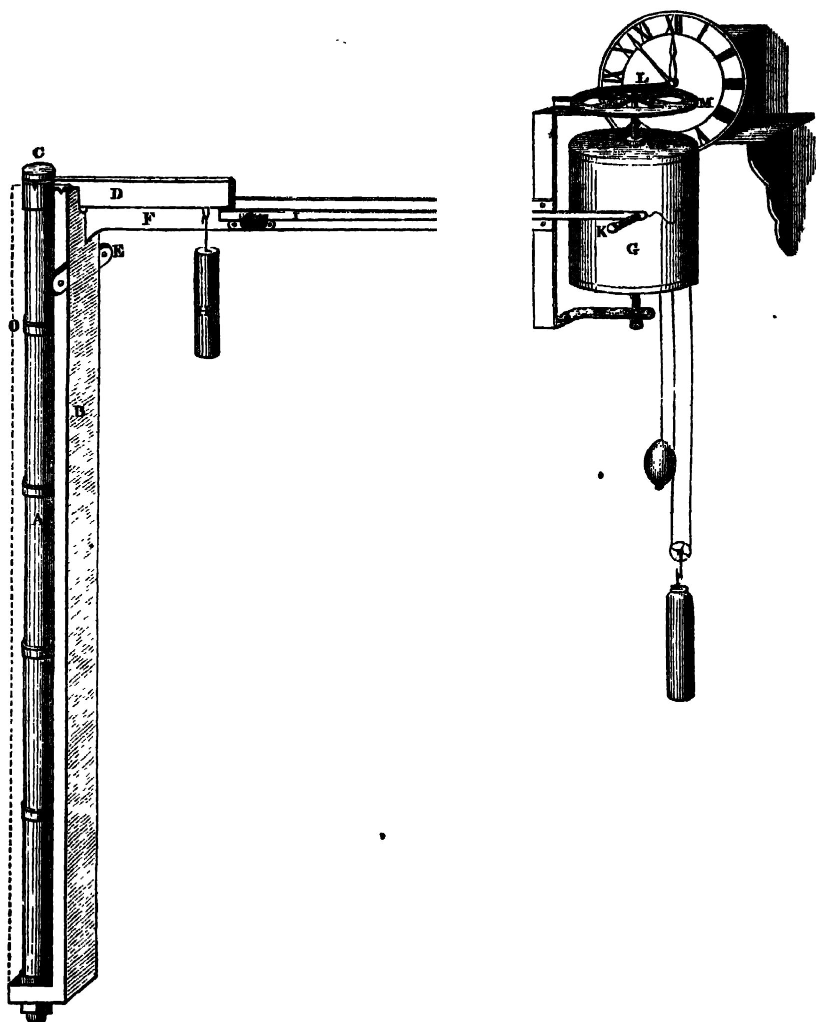
Cambridge Observatory, August 9, 1848.

On a Self-Registering Thermometer.

By MANSFIELD HARRISON (*in a letter to* Professor PHILLIPS).

The principle on which the instrument is constructed is the difference in the expansion and contraction of two metals, from the effects of heat and cold, and it acts by the direct pull of the contracting metal, when it is kept in a perfectly straight line. It is made sufficiently powerful to overcome any resistance which the fulcra of the levers or the tracing-pencil may cause. I have selected cast iron and hard rolled copper as the best suited for the purpose. I find from tables published by Smeaton and others, that copper expands $\frac{1}{525}$th of its length, while cast iron only expands $\frac{1}{910}$th, with a variation of 180° of Fahrenheit's thermometer, which leaves a difference of about the $\frac{1}{1260}$th of its length; and as the range of the thermometer in the shade in this climate is about 90°, or half of 180°, I have the $\frac{1}{2520}$th part of the length of the copper bar employed as a moving power. I fixed upon a bar 10 feet long as being a convenient length; the two metals will then vary nearly the one-and-twentieth part of an inch between the hottest day in summer and the coldest day in winter. This variation I multiply by means of a compound lever, so as to get a sufficient scale to divide. The end of the last lever carries a pencil which traces upon a revolving cylinder the variations that take place. In order to divide the scale accurately, I procured a standard thermometer by Troughton and Simms; I placed it in the same situation, and made several observations in the day, for some weeks, in the spring of the year, when the range of the thermometer is the greatest. After I had got the scale properly divided, I engraved it on

a plate of copper, in order to get a number of copies printed. The only attendance the instrument now requires, is to put a fresh paper upon the cylinder, by means of stretching-screws fixed on one side of it, once a week, when I wind the time-piece up.



Tabulated results for the year 1847, *taken from tracings by the instrument described.*

General mean of whole year			47·89
...	...	January	36·61
...	...	April	44·13
...	...	July	61·80
...	...	October	49·35
Highest single observation, 1st of August			80·00
Lowest single observation, 13th of February			22·00

A, copper bar, one inch in diameter and ten feet long. B, cast iron trough, to

which the copper bar is made fast at the bottom. C, brass cap soldered fast to the copper bar, with knife-edges on the under side, which rest on the tubular end of the first lever D; its fulcrum rests on the upper end of the cast iron trough B. E, flanges to bolt the trough to the outer side of a wall, near the angle of a room. F, part of the cast iron trough which passes through the wall into the room, carrying the fulcrum of the second lever I, and to which the revolving cylinder G is fixed. H, a weight to keep the first lever D steady on its bearings, and to counterpoise the second lever I. K, tracing-pencil. L, a screw working in the edge of the wheel M, and coupled to the minute-hand of the time-piece, making one revolution in an hour; the wheel M is fixed to the axis of the cylinder, and has 192 threads cut in its edge, and would make one revolution in eight days. N, a binding-screw to adjust the pencil to the proper hour-line, when a fresh paper is put on once a week. O, brass rings, made fast to the cast iron trough, to keep the copper bar steady, but through which it can move; the dotted line shows the side of the iron trough.

Comparative Temperature Table, showing the daily average height of the Thermometer; at Jersey, in 49° 11m N.; at Torquay, 50° 30m N.; Hastings, 50° 52m N.; and London, 51° 30m N. By J. W. Childers.

Daily Mean Temperature.

1848.	Jersey.	Torquay.	Hastings.	London
July 1.	55·2	55·5	No Returns.	52·5
„ 2.	58·0	58·0		59·0
„ 3.	63·0	59·5		59·5
„ 4.	60·7	62·5		60·5
„ 5.	67·0	62·0		66·0
„ 6.	71·0	63·0		73·5
„ 7.	62·0	61·0		62·5
„ 8.	60·0	60·0		60·5
„ 9.	61·3	60·5		60·0
„ 10.	60·7	63·5		59·5
„ 11.	61·0	65·0		60·0
„ 12.	62·0	68·5		64·5
„ 13.	63·7	67·5	71·0	67·0
„ 14.	64·2	62·0	72·5	73·5
„ 15.	63·0	62·0	59·0	56·0
„ 16.	60·0	65·5	63·0	63·5
„ 17.	62·7	63·0	71·5	61·5
„ 18.	65·0	61·5	64·5	65·5
„ 19.	64·7	59·5	67·0	66·5
„ 20.	61·0	60·0	62·0	58·0
„ 21.	65·5	64·0	64·0	61·0
„ 22.	65·0	60·5	67·5	69·0
„ 23.	69·5	62·0	64·0	64·5
„ 24.	60·3	62·5	67·0	62·0
„ 25.	62·3	59·5	60·0	60·5
„ 26.	64·3	59·5	63·0	59·0
„ 27.	64·0	62·5	61·0	61·5
„ 28.	63·2	64·5	62·5	63·0
„ 29.	61·0	62·5	64·5	64·0
„ 30.	64·3	62·5	66·0	65·5
„ 31.	62·0	59·5	64·5	61·5
Average	62·5	61·3	64·0	62·7
Highest	78·0	75·0	84·0	88·0
Lowest	49·0	51·0	47·0	37·0
Mean	63·5	63·0	65·5	61·5
Range	29·0	23·0	37·0	49·0

By the foregoing table it appears that Jersey and Torquay have the most moderate temperature, the extremes being only 29° and 24°, whereas at Hastings and London they are 37° and 49° —not rising above 78° and 75° at the former, and as high as 84° and 86° at the latter, whereas at the latter two, the thermometer fell to 47° and 37°: at the former only to 49° and 51°.

The highest temperature was reached at Jersey on the 6th, at Torquay on the 15th, at Hastings on the 17th, and in London on the 6th. The lowest, at Jersey, Torquay and London on the 1st, and at Hastings on the 15th. The barometrical pressure was very uneven in Jersey: the mercurial elevation varied from 30·475 to 29·386, its greatest elevation being on the 13th; its greatest depression on the 24th. At Torquay, the greatest elevation was on the 12th, 30·404; the greatest depression on the 20th, 29·343. At Hastings, the elevation was 30·404 on the 13th, the depression, 29·365 on the 20th. In London, the greatest elevation was on the 12th, 30·448; the greatest depression, 29·299, on the 20th. The mean pressures were—Jersey, 29·630; Torquay, 29·943; Hastings, 29·806, and London, 29·860: showing that the unsettled state of the weather was caused by effects not indicated by the barometer.

Extracts from a Letter to Professor WHEATSTONE *from* J. D. HOOKER, *M.D.*

Dearee, West Bank of Soane River,
Main road to Benares, Feb. 15, 1848.

"During our three days' stay at Cairo I made a few observations on the effects of the sun's rays on the soil, of the depth to which the heat penetrated, as also of the power of nocturnal radiation and thickness of soil through which the heat is radiated. In all these observations I find the great difficulty to be in selecting a position where the instrument shall itself be screened from radiation. Limestone, sand and sandstone rock, in the desert, have all different temperatures, and, except a brisk wind be stirring, give very different results. At the great Pyramid I selected two stations, each I thought unexceptionable; one at the N. face of the N.E. angle, the other at the W. face of the N.W. angle, and was mortified to find as much as 5½° difference in the temperature, and several in the dew-point, &c. At each angle I shifted the instruments from one to the other face, with the same results. At the summit there was considerably more vapour in the atmosphere than at the base. The temperature of the two chambers agreed (78°). On the Desert, midway between Cairo and Suez, I found a little before sunrise, after a very cold night, the dewy surface to be cooled down to 44° (if in shade 47°), and the increase of temperature to be 1° an inch down to 10 inches; similar soil on the previous and succeeding day was heated (at 3 P.M.) to about 80°, and the power of the sun's rays penetrated to more than that distance.

"At Suez we embarked on board the Hon. Company's steam-frigate 'Moozuffer' for Calcutta, and I observed three times a day the temperatures, dew-point, &c., but not the barometer, for my 'Newman's Portable' pumped so much as to render it impossible to observe within two-tenths of an inch; this was owing to the great power of the engines. Some of the phænomena are very curious. In the first place, the waters of this Gulf are salter than those of any other sea having a free communication with the greater oceans, and contains three-tenths more salt in an equal bulk than the Indian Ocean does. This high specific gravity decreases on the passage down to Mocha, where the increase is diminished to two-tenths, and suddenly to the usual standard of sea-water. My attention was first drawn to this by the chief engineer, with whom I conducted such experiments as the motion of the vessel allowed. During Ross's voyage I frequently examined the water (with Capt. R.), and whether from the various oceans we passed through, or different depths (down to 800 fathoms) in those oceans, always obtained a very constant quantity of salts. I also inquired about the waters of the Persian Gulf, and am assured that they do not differ from that of the Indian Ocean. From the Straits of Bab-el Mandeb to Cape Comorin I perceived no difference. There are further three classes of winds in the Red Sea, very remarkable in their distribution. During all June, July, August and September a north wind prevails throughout the sea, produced I suppose by the heated continents of Arabia, and especially Africa; and the

same wind continues all the year round from Suez to the Straits of Jubal, and with particular violence down the Gulf of Akabar. During the remainder of the year the winds in the middle part of the sea, from Jebbel-Teir, 15·30 to 19° or 20° N., are light and variable. In the south part, again, from Jebbel-Teir to the Straits, the S.E wind is constant from October till May, increasing in violence as you approach the Straits. This we experienced ourselves, for we carried N. and N.E. winds from Suez to lat. 20, variables from lat. 20 to Jebbel-Teir, and southerly from Jebbel-Teir to the Straits. I do not know how far the accompanying phænomena may account for the great saltness and well-known depression (below the level of the Mediterranean and of the Straits amounting, if I remember aright, to 35 odd feet) of the upper part of the sea; my observations give the following results:—

	Mean air temp.	Sea.	Wet-bulb therm.	Dew-point.	Vapour in cubic feet.	Calculated evaporation
Suez to lat. 20°...............	76·1	78·0	68·3	64·1	6·841	1·56
Lat. 20°, Jebbel Teir	81·6	80·4	74·5	71·4	8·478	1·38
Jebbel Teir to Straits	80·3	76·0	70·2	65·0	4·311	2·61

"The perennial north wind of the upper portion may of itself reduce the level; it is, further, a drier wind, and effects more evaporation from the surface than do the winds of the middle portion, at which it arrives loaded with vapour and increased in elasticity. Whatever evaporation takes place at the south portion again, during the dry south wind, may be compensated by an indraught from the Indian Ocean. The central portion again, during the same season, receives the loaded currents from either quarter, which its high temperature enables it to retain, its elasticity being also very high.

"Few other phænomena of any importance occurred to me during the voyage, except a curious variety I suppose of the crepuscular arch, which I witnessed on two nights after leaving Madras roads. The first I saw on January 9th at 6¾, while still in sight of land; it lasted hardly a minute after I first caught it, and appeared like a broad lunar rainbow over the sun's position, and about 70° alt. On the following evening I looked out for it; we were some 150 miles on our course to Calcutta. At three-quarters of an hour after sunset a pale milk-white arch, with the faintest tinge of purple, appeared at 60° alt. It was about 8° broad, the north end rested on a very faint cirrhus, alt. 30°; the southern descended lower, but did not reach the horizon; its limits were not clearly defined; it rose rapidly, and disappeared in about three or five minutes on reaching the zenith. The days had in both cases been very fine and clear, the sky at the time deep blue gray, with a peach-blossom tinge (for twilight) resting on a yellow horizon. This peach colour is a very common tropical sunset, and for delicacy of tint unequalled. At Aden, where contrasted with the stern pitchy dark crags of that peninsula and deep blue of the ocean, it produced the finest sunset effect I ever witnessed."

After describing some particulars of his instruments and methods of meteorological research, the author adds,—"I have twice had bores made of 3 and 4 feet at places 14' apart, and in both cases had a constant temperature of 72° for fifteen hours of afternoon and night; but this alluvium is often *too hard to bore* with common tools; it always takes six hours and six men to work the jumper. I guard the bulb with pith and sink it in a brass tube. The dryness of the upper plains we traversed is wonderful during these N.W. winds. I have been very careful with the wet-bulb observations. Solar radiation is all but impracticable; I persevere in the black bulb and wedge of glass photometer, made as you recommended by Darker.

"Last night I saw the best-developed aurora I ever witnessed, taking brightness, extent of surface covered, and length and continuity of beams into account: never in Scotland, where I have seen many, or the South Pole, where also they were frequent, have I seen one so altogether good as this. The moon spoiled it sadly, though its beams were brilliantly defined within 8° of her orb on each side. I send you the observations I took of it with a good quadrant and compass, from my first seeing it till it had nearly disappeared at midnight. I have also sent an account to be published in Calcutta, and hope it has attracted observation elsewhere. There is no change in the weather since, but much cirrhus since noon to-day, which is un-

usual, though possibly owing to the hills we are now close to, and which are new features in our landscape.

"Monday, Feb. 14. Barroon, East bank of Soane River, 9 P.M. Barom. 29·924; Atmos. temp. 58; Temp. air 62; Wet-bulb 51·5; Grass 53. Blue sky and clear horizon; moon and stars clear; milky way invisible; zodiacal light invisible; moon by photometer 3·07 inches (sun at 3 P.M. being 4·17 inches).

"Observed the *auroral arch* well defined, 12° broad; alt. of upper limb (best defined) 20°. Extremes bearing W. 20 S. and N. 50 E. Light, pale but bright, resting on an arch no darker than sky at zenith. *Beams* crowded, from 20 to 30 linear and lancet-shaped, crossing the zenith and converging in opposite horizon towards S. 15 E. All beams bright, clear and well-defined, moving slowly, forked at the apices or split from apex to zenith, almost obscuring stars of first magnitude. Longest beams point to S. 10 E. descending to 25° alt. Middle beam broad, crosses zenith, points S. 50 E. and descends to 40°. N.W. beams almost parallel to horizon, point S. 70 E. and descend to 20°.

"10 P.M. General appearance more diffused, upper limb of arch less defined. No beams cross the zenith. Two detached ones 15° above horizon at S. 15 E.; after a few minutes one beam reappeared on zenith.

"10h 15m. Appearance to W. of N. as before. One beam on zenith, two cross the meridian, one to S. 30 E. at 15° above horizon, which disappears towards the arch in S.E. Arch more diffused and descending to horizon, forming a pale mass, alt. 25°. Beams broader, shifting and splitting more frequently. Soon a dark horizontal band 4° broad crosses the arch, extending from N. 55 W. to N. 10 W.; upper limb 12° alt.; it appears as a break in the auroral arch. Whole horizon all round covered with a pale diffused light, strongest towards arch and in opposite quarter. Beams still clear, the lateral broadest and best defined. Dark band becomes broader, breaking up the arch.

"10h 30m. Beams from arch still clear, linear 2° to 6° broad, about 12 in number; none reach the zenith; a few lateral ones cross the moon's meridian, the upper approaching within 8° of her orb, and still well-defined. N.E. beams most crowded; N.W. best defined and broadest. Dark band broader, severing the arch. Whole phænomena fading: longest and brightest and most numerous beams stretching along N.E. horizon.

"10h 50m. Still fading. Beams and arch all disappear to W. of N. 18 narrow beams between N. and N. 20 E. from remains of arch. Cold southerly breeze sprung up.

"10h 55m. Breaking up as before.

"11 P.M. Diffused light over all horizon (possibly reflexion of moon's light on ground mist, which however is not discernible). Scattered beams like *cirrhus* here and there; linear along N. and N.E. horizon.

"Midnight. Two faint beams to N.E., and two strongly-defined lance-shaped parallel ones to S.W."

On a General Law of Electrical Discharge.
By Sir W. Snow Harris, *F.R.S.*

An interesting discussion having arisen, at the last Meeting of the Association at Oxford, relative to the laws and nature of the attractive force between two conducting spheres electrically charged, the author was led to undertake certain experimental investigations with a view of verifying the application of a series by Professor W. Thomson, of Glasgow, (relative to this interesting physical question) who, by a peculiarly striking and very elegant method, had associated such forces with the principle of optical reflexions, conceiving that in the common case of electrical attraction between two conducting spheres, certain electrical reflexions or images of force, as it were, may be conceived to be continually reflected between the bodies *in infinitum*, and that, by a particular series which he had deduced for such forms of action, the problem might be completely brought under the dominion of analysis.

The object of the present paper was to determine principally the relative degree of force between two conducting spheres at the instant of discharge, and to compare that with the quantity of electricity requisite to produce the discharge at given distances taken between the nearest points of the spheres.

In the following table will be found the results of the first series of experiments, in which is given—the distance in inches between the nearest points of the spheres (a); the measures or quantity of electricity requisite to produce an attractive force of 1 grain (b); the measures or quantity of electricity requisite to produce discharge at the given distance (c); the force of attraction at the instant of discharge (d).

Table I.

Distance in inches.	Quantity for force of 1 grain.	Quantity for discharge.	Attraction in grains at instant of discharge.
0·1	6	26	18 to 19
0·2	9−	52	38
0·3	11	78	50
0·4	13	104	64
0·5	15+	130	75
0·8	20	208	108
1·0	23	260	127
1·5	30+	390	169
2·0	38+	520	187
a	*b*	*c*	*d*

The electrical apparatus employed in these experiments was the same as that formerly described, and consisted of a common balance so circumstanced as to measure the relative attractive forces; a unit-measure for measuring the quantity of electricity; a large electrical jar, and a Lane's discharging electrometer placed in connection with the former, by which the relative quantity requisite to produce discharge at a given distance could be estimated.

In the above table, the last column d is deduced from columns b and c by the now well-established law of electrical action, viz. that the force is as the square of the quantity of electricity; the four last numbers in column c are deduced from the general law of the discharging electrometer, as observable in the preceding experiments of that column, and are taken as the number of measures which would be requisite to produce discharge at the given distances in column a, supposing the electrical jar capable of containing the given quantity.

Now, on reviewing these results, there does not appear to be any general law or relation between the numbers representing the force, as measured by the balance and given in column d, and the comparative quantities of electricity required to produce discharge, as given in column c; so far the experiments do not appear to furnish any very satisfactory result.

On examining the question, however, more attentively, it will be seen that the calculated force in column d is not really the force at the instant of discharge, taken between the nearest points of the spheres, that is to say, the points upon which the whole force is finally concentrated, and between which the discharge takes place, as evidenced in the balls of the discharging electrometer; hence column d does not actually represent the force in these points at this instant; it, in fact, only represents the general attractive force upon the whole of the opposed hemispheres, or rather in two points $q\,q'$ taken within the opposed surfaces, in which we may suppose the whole force to be collected, and to be the same as if operating from every point of the hemispheres.

The author proceeds to show how these points $q\,q'$ may be determined, and according to the formula $z = \frac{(a^2 + 2\,a\,r)^{\frac{1}{2}} - a}{2}$, in which z = distance of points $q\,q'$ under the surface a = distance of the nearest points of the sphere, and r = radius.

Supposing both spheres equal and radius = 1, then, according to the author's general results, brought under the consideration of the Section at the last Meeting, we have the total force between the spheres in the inverse ratio of the squares of the distances between the points $q\,q'$, or calling F the total attractive force we have $F = \frac{1}{a\,(a + 2\,r)}$.

The points $q\,q'$ therefore are calculable as to position and distance, and they are found to recede further and further from the surface as the distance between the nearest points of the spheres increases; it is only at an infinite distance that they can coincide with the centres of the spheres.

Taking the force of the attraction to vary in the inverse duplicate ratio of the squares of the distances, it is not difficult to determine the force in the points of discharge from column d of the last table, supposing that column to represent the force in the points $q\,q'$ at the instant of discharge.

With this view, the author was led to the results given in Table II., in which is given, as before,—distance between the nearest points (a); measures equal to a force of 1 grain (b); measures to produce discharge (c); attractive force in points $q\,q'$ at the instant of discharge (d). To which is now added, distance of points $q\,q'$ within the hemisphere (e); distance of points $q\,q'$ from each other (f); calculated force at the nearest points given in column a and taken at the instant of discharge (g); this last column being deduced from columns (a) and (f).

Table II.

Distance of the near points.	Measures for a force of 1 grain.	Measures for discharge.	Force in the points $q\,q'$.	Distance of points $q\,q'$ within the spheres.	Total distance of points $q\,q'$.	Calculated force in nearest points.
0·1	6	26	18 to 19	0·179	0·458	383
0·2	8 to 9	52	33 to 37	0·231	0·663	385
0·3	11	78	50	0·265	0·830	382
0·4	13	104	64	0·290	0·980	384
0·5	15–	130	76	0·3	1·111	380
0·8	20	208	108	0·348	1·497	379
1·0	23	260	127	0·365	1·73	381
1·5	30 to 31	390	162	0·395	2·29	378
2·0	37 to 38	520	190	0·419	2·83	380
a	b	c	d	e	f	g

What the author wishes to call attention to in this table is, that the force in the nearest points at the instant of discharge, as represented in the last column g, is at all distances a constant quantity, the numbers in column g not differing more than may be conceived to arise from the differences incidental to such experiments, a result quite in accordance with certain deductions arrived at by the author in former researches and printed in the Royal Society's Transactions for the year 1834, p. 227, and since confirmed by Faraday in the course of his admirable Electrical Researches, p. 449, § 1410.

The author concluded this communication by observing that he does not value these results, however interesting the experiments from which they have been derived, further than in proportion to their importance in tending to elucidate an interesting department of science, and afford us some further insight into the nature and mode of operation of a most wonderful agency.

With respect to the first object of these experiments, namely the verification of certain series employed by Professor Thomson, he leaves that, in the absence of Professor Thomson, to a future Meeting of the Association; he would merely observe, that the deductions from these new experimental inquiries correspond very fairly with the general formula he has given for such forces in electricity.

On the Mechanical Equivalent of Heat and on the Constitution of Elastic Fluids. By J. P. Joule.

At the last meeting of the Association the author exhibited an apparatus which by the agitation of fluids produced heat in exact proportion to the mechanical power expended. Experiments were made with this apparatus on the heat evolved by the friction of three totally dissimilar fluids—water, mercury and oil; and in all three cases the remarkable result appeared, that the mechanical power represented by the force necessary to raise 782 lbs. one foot high produced the quantity of heat equal to raise the temperature of a pound of water one degree.

Since the above experiments were communicated to the Association a slight alteration in the form of the apparatus, calculated to give greater exactness to the results, occurred to Mr. Joule, and he has therefore commenced a new and extensive series of experiments in order to determine the equivalent of heat with all the accuracy which its importance to physical science demands. The result arrived at after a series of forty experiments was an alteration of the equivalent before stated to 771, which is believed to be within $\frac{1}{200}$dth of the truth, and therefore may for the present be assumed as a tolerably good basis for calculation.

The author conceives the following points to be established:—1st. His experiments on the friction of fluids, confirming the views and experiments of Davy and Rumford on the friction of solids, afford another decisive proof that heat is simply a mechanical effect, not a substance. 2nd. His experiments, showing that the thermal effects of the condensation and rarefaction of air are the equivalents of the mechanical force expended or gained, prove that the heat of elastic fluids consists simply in the *vis viva* of their particles; and 3rd. The zero of temperature, determined by the expansion of gases, is at 491° below the freezing-point of water.

We may, the author thinks, employ the above propositions as a basis on which to calculate the specific heat of the gases. For whether we conceive the particles to be revolving round one another, according to the hypothesis of Davy, or flying about in every direction according to Herapath's view, the pressure of the gas will be proportional to the *vis viva* of its particles. Thus it may be shown that the particles of hydrogen gas at the barometrical pressure of 30 inches and temperature 60°, must move with a velocity of 6225·54 feet per second in order to produce the observed pressure of 14·714 lbs. on the square inch. Now a lb. moving at that velocity is equivalent to 781°·45 of heat in a lb. of water, which will therefore represent the absolute heat of a lb. of hydrogen at 60°. But 60° is, as already stated, 519° of temperature from zero, whence $\frac{781^\circ{\cdot}45}{519} = 1{\cdot}5157$ will be the heat required to raise the temperature of a lb. of hydrogen 1°, compared with that necessary to give the like increase of temperature to a lb. of water, in other words, 1·5157 will be the specific heat of the gas.

Further, since oxygen is 16 times as heavy as hydrogen, its particles must move at one-fourth the velocity in order to produce the same pressure. The specific heat of oxygen (as of all other gases) will be inversely as its density, or = 0·09473.

	Theory.	Experiments of De la Roche and Berard referred to capacity at constant volume.
Hydrogen	1·5157	2·3520
Aqueous vapour . .	0·1684	0·6050
Nitrogen	0·1074	0·1953
Oxygen	0·0947	0·1686
Carbonic acid . . .	0·0685 "	0·1579

Notices of Auroræ observed at Swansea. By John Jenkins, *F.R.A.S.*

Dec. 3, 1845, after a general luminosity in the north, a flat elliptical arch, from near the vertex of which two pyramidal coruscations shot up to the zenith, growing fainter upwards, while a third rose between the crown and the northern extremity of the arch. At half-past 8 the arch was higher, its upper edge nearly intersecting the Pleiades and passing through Gemini and Taurus. Its breadth = 1½ diam. of the moon, light yellowish.

Sept. 29, 1847.—At a quarter past 7 this fine aurora had the appearance of a white striated band extending from E. to W. and crossing the zenith. Jupiter was about 1 diam. of the moon from the upper margin of the brush near the eastern horizon.

Oct 24, 1847.—The characteristic radiating canopy of light of this great aurora was observed at Swansea; light red and filmy, vanishing round the moon in a circle, whose radius was 6 lunar diameters. Apparent motion of the light upwards; light brightest in the N.W., where silvery as well as red pencils were constantly emitted. To the N.E. of the moon near the zenith, a partial halo or corona was formed,

Tables of Meteorological Phænomena observed at Swansea.
By JOHN JENKINS, *F.R.A.S.*

In presenting to the British Association the accompanying records of the Meteorological Phænomena observed at Swansea, I can only hope they are of value as adding to the number of continuous and regular observations by a series taken at a position far separated from any other spot where similar observations are registered; this being the only series, as far as I am aware, obtained in Wales.

Any attempt to examine the occurrence of instrumental registries which gave anomalous indications, would be occupying time with an inquiry that can be better prosecuted in the study, and then when assisted by a long series of corresponding observations. There are, however, some local conditions which it will be desirable to notice, that the great difference between these tables and others taken at stations dissimilarly situated may be explained. The first relates to temperature.

A comparison of the temperature of the inland towns of England with the temperature of Swansea would surprise the casual inquirer; for instance, the temperature of May 1844 was unusually low. On Friday the 17th, the thermometer at the Dock-master's office, St. Katherine's, London, stood at 51°, while at Swansea, in the open air, the mean temperature on that day was 60°. Again, on the 24th of June, at 7 A.M., the thermometer at London stood in the shade at 70° Fahr.; at Swansea, on the same morning at 9 A.M., 66°; deducting the increase of temperature for two hours, 2°·5 per hour, the temperature at Swansea was 61°, being 9° less than at London.

These considerable variations are to be accounted for by the position of Swansea, being on the margin of an extensive bay communicating with the Bristol Channel. The temperature of its water, being in the first example above the temperature of the air, imparted so much heat to the atmosphere as to modify the cold to the amount mentioned; while, in the second instance, the water in the bay being below the temperature of the air lowered the thermometric indication.

2ndly. The direction of the wind is given for the total number of days in each month, from daily observations taken at 9 A.M. and 3 P.M., when the other registries of the instruments are made. This direction must not be regarded as the direction of the great aërial wave, but of the current modified by the headlands, which extend to the peninsula of Gower on the west and Kilvay Hill with its contiguous high lands on the east; a correction consequently becomes necessary when comparing the direction of the wind at Swansea with other places not similarly circumstanced. Careful registers kept at the Nash and Mumbles light-houses and Wormshead, would enable tables of equation to be constructed for such correction.

3rdly. The time and height of high water.

Swansea Bay being situated at the mouth of the Bristol Channel, and having its shores lashed by the waves of the Atlantic, often exhibits in its undulations the impression of distant gales propagated over the surface of that broad mass of water long before the atmospheric disturbance itself has reached the coast.

The height of the tidal wave in Swansea Bay is consequently dependent on the direction and force of the wind passing over the Atlantic, being increased when westerly and reduced when easterly. Another influence which belongs to this subject, although of minor import, is the pressure of the atmosphere at the time of high water. La Place seems to think that this flux and reflux at Paris is attributable to the tidal waves which form a variable base to the atmosphere.

The Swansea tide tables contain the heights of water in the river for every day during the year; but these tables being computed without reference to the disturbing causes alluded to, their accuracy is destroyed as often as the wind blows strongly from either of the points mentioned. Thus the depth of water on the bar is not always the greatest on the day mentioned in the Tide Table. This discrepancy occurred during the high tide of 1846, when the highest tide did not occur on the day stated in the Tide Table, but, on the contrary, the second tide on the following day was the highest. Again, on one occasion, in the Tide Table the depth of water on Swansea bar is stated to be 23 feet, whereas it amounted to 30 feet; an increase in the tidal wave equal to two-thirds the average depth of water on the bar at high water during the lowest neap tides.

It is much to be desired that the amount of disturbance occasioned by the various winds should be ascertained and arranged as the equation table is for the sun-dial, so that persons who may be interested in the inquiry may be enabled to ascertain the accurate height of tide at high water.

Tables of Meteorological Phænomena

Barometer.			Hygrometer.								
Mean height.	Highest.	Lowest.	9 A.M. Dry.	9 A.M. Wet.	Diff.	3 P.M. Dry.	3 P.M. Wet.	Diff.	Mean temp. of day.	Mean temp. of night
30·25 a.m. 30·24 p.m.	2, 3, 30·57 p.m.	26, 29·60 p.m.	65·9	59·5	6·4	70·0	61·9	8·1	70	66
30·03 a.m. 30·05 p.m.	15, 30·45 a.m.	11, 29·63 a.m. & p.m.	64·0	59·7	4·3	66·2	61·3	4·9	66	64
30·17 a.m. 30·08 p.m.	31, 31·30 p.m.	10, 29·79 p.m.	66·9	64·3	2·6	69·9	66·2	3·7	71	67
29·92 a.m. 29·92 p.m.	3, 4, 14, 30·26 a.m. & p.m.	24, 29·44 a.m.	61·1	58·0	3·1	62·9	58·6	4·3	63	60
30·05 a.m. 30·05 p.m.	9, 30·55 p.m.	23, 28·98 a.m.	51·5	48·8	2·7	53·3	50·3	3·0	53	50
29·71 a.m. 29·51 p.m.	17, 30·42 p.m.	24, 28·85 a.m. & p.m.	46·6	45 5	1·1	47·3	46·2	1·1	46	45
30·06 a.m. 30·06 p.m.	19, 30·46 a.m. & p.m.	27, 29·38 a.m.	47·7	46·9	0·8	48·2	47·5	0·7	47	47
29·81 a.m. 29·76 p.m.	19, 30·47 a.m.	12, 28·13 p.m.	43·7	42·3	1·4	44·9	44·0	0·9	44	43
29·68 a.m. 29·66 p.m.	12, 30·08 a.m. & p.m.	27, 28·91 p.m.	39·3	37·5	1·8	41·0	39·3	1·7	40	37
29·98 a.m. 29·65 p.m.	29, 30·60 p.m.	21, 22, 29·43 p.m. & a.m.	45·8	44·0	1·8	48·9	46·8	2·1	48	45
29·91 a.m. 29·93 p.m.	15, 30·23 a.m. & p.m.	4, 29·41 a.m.	51·8	50·9	0·9	53·9	53·1	0·8	54	50
29·90 a.m. 29·89 p.m.	11, 30·30 p.m.	16, 29·59 a.m.	57·7	56·5	1·2	58·8	57·8	1·0	58	57
29·97 a.m. 29·88 p.m.	21, 30·32 a.m.	3, 29·14 a.m.	61·8	59·5	2·3	63·6	60·9	2·7	68	51
30·14 a.m. 30·16 p.m.	16, 17, 30·46 p.m. & a.m.	5, 23, 29·77 p.m. & a.m.	64·4	61·6	2·8	66·7	63·4	3·3	71	52
30·11 a.m. 30·12 p.m.	12, 30·43 a.m. & p.m.	22, 29·67 p.m.	66·3	63·5	2·10	69·1	65·1	4·0	72	51
30·34 a.m. 30·34 p.m.	23, 24, 30·70 p.m. & a.m.	15, 29·92 a.m.	64·7	60·8	3·9	68·0	64·0	4·0	72	51
29·89 a.m. 29·93 p.m.	19, 30·52 p.m.	27, 29·28 p.m.	52·2	50·2	2·0	53 6	51·8	1·8	57	43
29·96 a.m. 29·97 p.m.	29, 30·58 p m.	23, 29·44 a.m.	45·6	45·1	0·5	47·1	46·2	0·9	50	38
30·50 a.m. 30·48 p.m.	24, 30·68 a.m.	31, 29·86 p.m.	48·0	47·4	0·6	49·0	48·4	0·6	51	44

bserved at Swansea.

Thermometer.			Date.	Direction of Wind in days.								Weather in days.			Remarks.		
Maximum on	Minimum on	No. of observ.		N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Dry.	Showery.	Wet.	Rain in inches.	tenths.	lines.
10, 12, 82	21, 58	58	1842. June	No observations taken on the wind in June.								22	7	1	1	4	2
16, 74	7, 57	62	July	7	2	2	7	3	23	10	8	20	8	3	2	0	3
17, 86	25, 56	62	August ...	3	11	1	4	6	23	1	9	20	7	4	1	3	8
1, 4, 69	20, 23, 51	60	September	2	19	0	6	0	13	3	17	21	5	4	4	0	8
9, 63	26, 38	62	October ...	1	24	3	4	0	4	2	24	21	8	2	3	0	0
ɔ, 11, 12, 13, 19, 51	6, 17, 39	60	November	0	11	3	16	4	12	5	7	10	11	9	9	6	0
13, 54	24, 27, 37	62	December	0	0	0	15	5	11	19	10	12	7	12	3	5	7
26, 28, 51	12, 32	62	1843. January ...	3	2	1	9	0	8	12	27	11	12	8	3	2	0
1, 21, 49	15, 26	56	February ..	2	29	6	12	0	1	1	5	21	4	3	1	4	7
19, 62	3, 31	61	March	1	5	7	29	4	14	2	0	19	6	6	1	5	9
19, 64	10, 12, 41	60	April	3	8	4	4	5	17	9	8	13	12	5	3	6	1
2, 68	4, 19, 20, 52	62	May	0	6	2	22	1	17	6	9	15	9	7	3	8	2
24, 27, 78	7, 2, 9, 44	60	June	1	11	3	7	0	22	7	12	17	9	4	2	7	7
11, 16, 80	21, 46	60	July	10	1	0	0	1	17	21	7	18	9	4	2	2	5
19, 84	22, 43	62	August ...	5	4	1	7	1	24	11	6	21	5	5	2	8	7
19, 81	28, 37	60	September	6	9	2	13	4	15	5	34	27	2	1	0	6	2
2, 4, 71	26, 30	60	October ...	0	6	1	6	0	12	3	8	14	11	6	4	9	1
4, 5, 6, 57	2, 30	60	November	8	6	4	9	5	10	10	8	12	12	6	5	7	2
16, 17, 18, 54	2, 13, 37	62	December	9	5	5	8	5	9	8	11	20	3	8	1	1	3

TABL

Barometer.			Hygrometer.*							
Mean height.	Highest.	Lowest.	9 A.M. Dry.	9 A.M. Wet.	Diff.	3 P.M. Dry.	3 P.M. Wet.	Diff.	Mean temp. of day.	Mean temp. of night
30·18 a.m. 30·18 p.m.	11, 30·56 a.m. & p.m.	6, 29·33 a.m.	42·1	41·7	0·4	44·3	43·5	0·8	48	37
29·78 a.m. 29·79 p.m.	21, 30·38 p.m.	25, 29·33 p.m.	40·3	38·8	1·5	41·9	41·1	0·8	45	33
29·97 a.m. 29·98 p.m.	29, 30·67 a.m. & p.m.	16, 29·48 a.m.	45·0	43·1	1·9	47·2	45·1	2·1	52	36
30·31 a.m. 30·30 p.m.	9, 30·68 a.m. & p.m.	4, 29·81 p.m.	54·2	50·9	3·3	57·2	53·2	4·0	62	41
30·32 a.m. 30·30 p.m.	2, 30·61 p.m.	7, 30·03 p.m.	60·8	54·3	6·5	63·5	57·0	6·5	70	41
30·14 a.m. 30·13 p.m.	16, 30·43 a.m.	18, 29·54 p.m.	63·1	58·5	4·6	66·3	61·0	5·3	71	52
29·84 a.m. 30·13 p.m.	26, 28, 30·45 p.m., a.m. & p.m.	30, 29·73 p.m.	66·4	61·2	5·2	69·5	63·2	6·3	69	64
30·01 a.m. 30·02 p.m.	19, 31, 30·44 a.m. & p.m.	3, 29·32 a.m.	61·6	58·3	3·3	64·7	60·8	3·9	64	59
30·22 a.m. 30·20 p.m.	1, 30·52 p.m.	17, 29·94 a.m. & p.m.	61·8	59·3	2·5	65·0	61·5	*3·5	64	60
29·84 a.m. 29·83 p.m.	27, 30·39 a.m.	15, 29·07 p.m.	52·1	51·3	0·8	54·3	53·2	1·1	54	51
29·91 a.m. 29·91 p.m.	21, 30·47 a.m. & p.m.	8, 29·08 p.m.	47·0	40·2	0·8	48·4	47·3	1·1	49	42
30·04 a.m. 30·01 p.m.	4, 30·36 a.m.	16, 29·32 p.m.	35·9	33·9	2·0	37·5	36·0	1·5	38	32
29·86 a.m. 29·86 p.m.	7, 30·28 a.m.	28, 20·11 p.m.	41·1	40·1	1·0	43·1	42·0	1·1	44	.36
30·01 a.m. 30·01 p.m.	12, 30·44 p.m.	23, 29·49 a.m.	36·8	35·4	1·4	39·7	38·2	1·5	40	32
30·08 a.m. 30·09 p.m.	21, 30·50 p.m.	3, 16, 29·78 a.m. & p.m.	39·8	37·5	2·3	43·5	41·3	2·2	44	32
29·94 a.m. 29·92 p.m.	16, 30·45 a.m.	9, 29·21 p.m.	52·9	49·3	3·6	56·7	52·6	4·1	57	44
30·02 a.m. 30·02 p.m.	15, 30·43 p.m.	10, 29·61 a.m.	56·7	52·5	4·2	58·9	54·8	4·1	60	46
30·07 a.m. 30·05 p.m.	9, 10, 30·47 p.m. & a.m.	5, 6, 29·58 p.m. & a.m.	64·6	60·6	4·0	67·6	62·8	4·8	69	53
30·04 a.m. 30·03 p.m.	5, 30·28 a.m. & p.m.	31, 20·62 a.m. & p.m.	64·2	61·0	3·2	66·6	62·9	3·7	66	54

* On Sunday night the 23rd of June and Monday morning, a thunder-

ntinued).

Thermometer.			Date.	Direction of Wind in days.								Weather in days.			Remarks.			
Maximum on	Minimum on	No. of Observ.		N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Dry.	Showery.	Wet.	Rain in inches.	tenths.	lines.	
6, 53	16, 27	62	1844. January ...	4	10	4	5	0	2	3	34				3	1	2	A heavy gale of wind, barometer not affected.
1, 15, 16, 49	23, 26	58	February ..	4	12	1	6	1	12	3	19	20	6	3	3	4	4	
27, 29, 30, 31, 58	7, 28	62	March	3	14	3	6	1	8	8	19	23	2	6	3	2	8	
26, 72	6, 34	60	April	3	1	0	9	3	29	10	4	28	0	2	1	1	5	
14, 79	19, 37	62	May	7	22	4	8	2	5	4	9	29	1	1	0	0	8	
30, 81	1, 46	60	June*......	1	4	0	6	1	30	9	9	27	3	0	1	2	7	
1, 23, 81	6, 17, 20, 48	62	July	6	2	0	5	2	17	8	22	27	4	0	1	7	9	
31, 73	16, 17, 47	56	August ...	3	1	0	8	2	13	7	28	20	11	0	4	8	7	
1, 2, 4, 76	30, 42	60	September	1	21	4	6	2	12	2	12	25	2	3	1	0	0	
4, 65	23, 24, 26, 38	62	October ...	1	8	0	15	1	12	5	20	15	15	1	5	3	4	
16, 17, 18, 20, 55	25, 32	60	November	1	13	4	19	1	8	8	4	22	4	4	3	8	5	
29, 48	10, 24	62	December.	0	9	29	24	0	0	0	0	24	4	1	0	4	6	
5, 49	29, 31, 28	62	1845. January ...	4	5	1	19	0	15	2	9	18	6	5	3	2	2	Jan. 12th, fog; 29th, snow.
24, 49	7, 27	56	February .	3	6	0	27	1	4	1	13	21	4	2	3	4	2	Feb. 10th, snow.
27, 55	14, 17	62	March	2	29	1	4	0	15	4	6	25	3	3	2	3	11	
23, 68	12, 34	60	April	2	14	0	17	1	18	3	4	20	5	5	2	5	0	April 22nd, thunder.
30, 70	7, 39	62	May	9	21	2	3	1	12	1	13	21	8	2	1	1	9	
13, 85	4, 46	60	June	0	4	0	3	1	25	0	12	17	11	2	3	1	9	
7, 19, 73	16, 29, 30, 47	62	July	1	8	0	7	3	25	5	13	21	8	2	3	4	6	July 2, min. and max. temp. alike.

The observations on the weather commenced in February.

rn ; on Tuesday the 25th a large halo round the sun.

TAB

Barometer.			Hygrometer.								
Mean height.	Highest.	Lowest.	9 A.M. Dry.	9 A.M. Wet.	Diff.	3 P.M. Dry.	3 P.M. Wet.	Diff.	Mean temp. of day.	Me tem of ni
30·00 a.m. 30·01 p.m.	29, 30, 30·45 a.m., p.m. & a.m.	9, 29·55 a.m.	62·5	59·9	2·6	64·9	61·5	3·4	64	5
30·03 a.m. 30·02 p.m.	1, 30·41 a.m.	19, 29·02 p.m.	59·7	57·7	2·0	62·1	59·9	2·2	62	5
30·09 a.m. 30·08 p.m.	23, 30·59 a.m. & p.m.	8, 29·29 p.m.	54·7	53·2	1·5	56·8	55·2	1·6	57	4
29·78 a.m. 29·76 p.m.	3, 30·35 a.m. & p.m.	19, 29·18 p.m.	49·4	47·6	1·8	50·9	49·0	1·9	50	4
29·92 a.m. 29·91 p.m.	12, 30·43 p.m.	20, 29·05 a.m.	44·7	43·4	1·3	46·2	44·6	1·6	45	3
29·83 a.m. 29·82 p.m.	9, 30·60 a.m. & p.m.*	19. 29·16 p.m.	47·1	46·0	1·1	48·3	47·2	1·1	48	4
30·05 a.m. 30·05 p.m.	10, 30·43 p.m.	24, 29·48 p.m.	46·6	44·8	1·8	49·2	47·2	2·0	49	4
29·88 a.m. 29·87 p.m.	12, 30·63 a.m.	23, 29·26 a.m.	48·5	45·6	2·9	52·0	48·6	3·4	52	3
29·83 a.m. 29·82 p.m.	30, 30·42 a.m. & p.m.	2, 29·19 p.m.	52·0	48·8	3·2	54·6	51·2	3·4	56	4
30·05 a.m. 30·04 p.m.	29, 30, 30·46 p.m. & a.m.	18, 29·06 a.m.	60·4	55·6	4·8	63·7	58·2	5·5	66	5
30·18 a.m. 30·17 p.m.	30·48 a.m.	29·72 a.m.	73·0	66·0	7·0	76·8	68·8	8·0	73	5
29·99 a.m. 29·99 p.m.	28, 30·34 a.m.	5, 29·35 p.m.	67·1	62·6	5·5	70·2	64·9	5·3	68	5
29·66 a.m. 29·64 p.m.	25, 3·41 a.m. & p.m.	29·57 p.m.	68·0	67·0	1·0	70·3	65·5	4·8	71	5
30·84 a.m. 30·83 p.m.	30·53 a.m.	29·49 p.m.	65·6	60·5	5·1	68·9	63·5	5·4	70	5
29·76 a.m. 29·73 p.m.	27, 30·35 a.m. & p.m.	15, 29·00 a.m.	54·1	51·8	2·3	56·5	54·0	2·5	57	4
28·94 a.m. 28·93 p.m.	10, 30·49 a.m.	20, 29·23 a.m.	48·7	47·2	1·5	50·7	49·0	1·7	49	4
29·95 a.m. 29·95 p.m.	30, 31, 30·55 p.m. & a.m.	23, 28·89 a.m.	37·3	36·1	1·2	39·1	37·8	1·3	40	3
29·52 a.m. 29·50 p.m.	1, 30·36 a.m.	24, 29·17 a.m.	39·5	38·3	1·2	41·3	40·4	0·9	43	3
30·00 a.m. 29·99 p.m.	21, 30·38 a.m.	8, 29·54 p.m.	39·9	38·0	1·9	43·0	40·9	2·1	44	3

* 8th of February heavy gale of snow from 9 to 1, during which time 8 inches fell, measured on a le

ntinued).

Thermometer.				Direction of Wind in days.								Weather in days.			Remarks.
Maximum on	Minimum on	No. of Observ.	Date.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Dry.	Showery.	Wet.	Rain in inches. tenths. lines.
30, 74	16, 17, 22 47	62	1845. August ...	4	4	0	0	0	19	5	30	17	11	3	6 4 6
1, 12, 69	24, 37	60	September	1	4	4	16	2	17	1	12	17	6	7	3 8 3
14, 62	26, 37	62	October ...	0	3	0	18	0	17	0	24	22	8	1	2 0 0
1, 56	23, 31	60	November	0	5	1	22	0	10	6	16	15	9	6	4 3 2
16, 52	22, 30	62	December	1	8	0	0	0	14	5	34	11	9	10	4 4 6 Dec. 13, mist.
29, 30, 31, 53	2, 34	62	1846. January ...	0	0	0	15	1	19	8	17	15	6	9	6 1 2
25, 28, 56	11, 28	56	February .	6	7	0	9	3	7	0	24	19	8	1	1 9 2
15, 58	19, 29	62	March ...	2	5	1	6	2	23	6	17	12	15	2	2 4 3
16, 61	7, 35	60	April	5	10	1	10	2	13	4	14	17	10	3	2 5 1
31, 76	15, 43	62	May	5	4	0	11	3	26	7	5	23	8	0	1 8 0
19, 89	24, 53	60	June	0	2	1	8	4	41	1	3	20	9	1	1 6 8
31, 84	19, 51	62	July	2	2	1	9	1	23	11	13	16	11	4	3 8 4
6, 80	14, 51	62	August ...	2	11	1	5	2	26	4	11	15	8	8	3 3 2
12, 77	29, 46	60	September	3	4	1	15	1	19	5	12	24	5	1	2 0 5
6, 64	27, 37	62	October ...	1	10	2	6	0	27	4	12	11	13	7	5 1 0
4, 60	30, 28	58	November	0	10	5	24	1	14	2	3	17	8	4	3 3 5
19, 20, 49	16, 23	62	December	6	28	0	2	0	4	3	12	23	3	1	2 9 9
23, 27, 49	12, 18, 19 28	62	1847. January ...	1	0	6	37	2	10	1	4	16	5	6	2 6 2 Jan. 2, snow and fog.
15, 16, 17, 52	27, 20	56	February .	1	15	3	9	2	8	3	14	17	6	2	2 4 8* Feb. 3, snow.

·h, snow all day at intervals. Mails from Llanelly cease to travel, bags being carried on horseback.

TABI

Barometer.			Hygrometer.							
			9 A.M.		Diff.	3 A.M.		Diff.		
Mean height.	Highest.	Lowest.	Dry.	Wet.		Dry.	Wet.		Mean temp. of day.	Mean temp. of nigh
30·06 a.m. 30·04 p.m.	3, 30·57 a.m.	20, 29·50 p.m.	46·3	43·8	2·5	50·0	46·7	3·3	51	38
29·89 a.m. 30·15 p.m.	20, 30·99 p.m.	8, 29·45 p.m.	50·9	47·6	3·3	54·0	50·0	4·0	59	41
29·95 a.m. 29·95 p.m.	31, 30·58 a.m.	8, 29·52 a.m.	60·0	55·8	0·2	64·3	58·7	5·6	68	50
30·09 a.m. 30·46 p.m.	18, 30·95 p.m.	15, 29·55 a.m.	62·8	57·9	4·9	67·8	60·4	7·4	75	52
30·20 a.m. 30·20 p.m.	1, 30·43 p.m.	7, 29·92 a.m.	68·2	63·5	4·7	72·6	67·	5·6	71	57
30·17 a.m. 30·16 p.m.	14, 30·42 a.m.	5, 29·71 p.m.	64·0	59·8	4·2	69·9	65·7	4·2	72	54
30·08 a.m. 30·09 p.m.	29, 30·34 a.m.	16, 29·67 a.m.	58·2	55·5	2·7	64·2	61·4	2·8	66	52
29·94 a.m. 30 05 p.m.	24, 30·82 p.m.	22, 29·14 a.m.	53·6	52·5	1·1	57·8	55·6	2·2	59	49
30·01 a.m. 30·23 p.m.	5, 30·95 p.m.	28, 29·19 p.m.	48·2	46·2	2 0	52·3	50·4	1·9	54	41
29·83 a.m. 29·83 p.m.	1, 30·35 p.m.	7, 29·07 a.m.	42·0	40·7	1·3	45·0	43·5	1·5	46	38
29·80 a.m. 29·94 p.m.	12, 30·48 a.m.	31, 29·12 a.m.	36·1	35·3	0·8	39·5	38·3	1·2	41	32
29·67 a.m. 29·63 p.m.	18, 30·46 a.m.	13, 28·00 p.m.	43·1	42·1	1·0	46·6	45·4	1·2	48	38
29·69 a.m. 29·61 p.m.	8, 30·28 a.m.	1, 28·92 a.m.	43·9	41·8	2·1	49·7	47·2	2·5	51	38
29·86 a.m. 29·87 p.m.	30, 30·20 a.m.	18, 29·28 p.m.	49 6	45·5	4·1	55·2	51·0	4·2	57	42
30·194 a.m. 30·308 p.m.	22, 30 42 a.m.	17, 29·51 p.m.	61·2	54·6	6·6	68.7	61·5	7·2	70	52
29·906 a.m. 29·905 p.m.	21, 30·32 a.m.	3, 29·44 a.m.	62·2	57·7	4·5	65 5	61·0	4·5	67	52
30·090 a.m. 30·149 p.m.	30, 30·84 p.m.	20, 30·84 a.m.	63·5	59·9	3·6	68·7	64·1	4·6	70	55

tinued).

Thermometer.			Date.	Direction of Wind in days.								Weather in days.			Remarks.		
Maximum on	Minimum on	No. of observ.		N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Dry.	Showery.	Wet.	Rain in inches.	tenths.	lines.
18, 58	1, 4, 32	62	1847. March	3	18	0	22	1	11	3	11	21	5	5	3	6 Rain.	7
13, 14, 20, 21, 29, 60	2, 30	58	April	4	8	0	3	1	17	11	16	15	10	5	1	5 Rain.	1
27, 28, 31, 74	4, 38	56	May	1	1	2	20	4	27	4	2	16	12	3	3	1	5
1, 81	11, 42	54	June	6	7	0	2	0	24	9	12	21	7	2	2	7	3
12, 81	23, 51	56	July	7	8	1	9	0	26	6	6	22	8	1	2	5	8
26, 79	4, 24, 46	54	August ...	6	15	0	0	0	15	2	24	19	9	3	3	8	8
1, 70	6, 41	54	September	4	1	0	8	0	13	10	24	11	15	4	3	3	2
12, 68	6, 39	58	October ...	1	2	3	23	2	16	5	10	13	10	8	7	3	1
6, 62	19, 31	60	November	4	5	1	14	0	16	6	15	13	9	3	2	7	8
2, 3, 54	22, 31, 29	60	December.	3	10	1	16	0	5	0	3	14	7	10	6	1	8
4, 54	28, 20	54	1848. January ...	11	24	3	10	2	5	0	7	21	7	3	1	2	4
28, 53	1, 28	58	February ..	3	2	0	2	3	29	5	18	13	7	9	6	4	3
31, 64	17, 31	62	March	9	8	0	9	1	4	6	20	17	7	7	3	9	9
3, 72	10, 33	60	April	13	12	1	7	2	12	2	8	16	8	6	3	6	0
14, 79	1, 44	62	May	4	6	0	8	4	30	3	6	26	3	2	2	2	6
19, 76	1, 42	58	June	1	1	0	8	0	30	8	12	8	15	7	3	4	6
14, 17, 80	1, 45	62	July	6	3	0	5	0	26	15	7	15	9	6	3	5	3

On Meteorological Observations continued at Alten in Finmark. *By* JOHN LEE, *LL.D., F.R.S.*

Dr. Lee presented to the British Association the observations made by Mr. J. H. Grewe at Alten in 1846 and 1847.

The annexed tables contain the principal results of those observations reduced to the English scale, the observations being made with French instruments.

These Meteorological Observations are a continuation of others presented by Dr. Lee to the Society at York, Cambridge and Southampton for the years 1843, 1844 and 1845, and which were made by Mr. Grewe and Mr. J. F. Cole.

The observations for 1846–47 have been made by Mr. Grewe alone, Mr. Cole having returned to England. They contain the twelve tables for the months, with the daily observations, as formerly, for 1846, and the same for 1847; also two tables with the summary of the contents and the results for each year.

The former observations for 1843, 1844 and 1845, contained in addition the half-hourly observations made on the 21st of each month, which have been discontinued, as Mr. Grewe had no assistance as formerly, and his avocations at the proper hours prevented him, as also did occasional illness. There was no want of zeal or inattention to the subject.

Mr. Grewe and Mr. Cole were both assistants in the employ of the British Copper Mining Association established at Alten, and only able to devote their leisure time to these subjects as an amusement and an object of gratification. They laboured under great disadvantages, not only from climate, but from the want of encouragement and the means of communicating with persons of science. They carried on their observations in a climate in which in the winter they could hardly touch their instruments, and where they are deprived of the light of the sun in the winter for several months. Notwithstanding these disadvantages, they fixed a thermometer on the highest mountain (Storvandsfjeld) to the west of the Alten Copper Works before the winter commenced, and examined it again in the spring. Dr. Lee recommended a similar experiment to be tried at Swansea. Also they observed the auroras during the winter, and in a former year presented a paper concerning them.

These Alten Observations have not been already without some use and interest. Col. Sabine has referred to them in one of his papers on the Meteorology of Bombay, and Mr. Birt, in his papers on the atmospheric wave, sets great value on the Alten Observations. So likewise do Mr. Ronalds of Kew and the Rev. Mr. Fisher of Greenwich.

With respect to the Christiania Observations, Dr. Lee remarked, that since his arrival at Swansea he had received the Christiania Observations for 1847 from J. R. Crowe, Esq., Her Britannic Majesty's Consul-General at Christiania in Norway.

They are a continuation of others made last year, and which Dr. Lee had the honour of presenting to the Association, in Mr. Crowe's name, at Oxford*. Mr. Crowe formerly was the British Consul at Alten, where he resided for several years, and it is in a great measure owing to his judgement and zeal that the meteorological observations were commenced at Alten, and continued, since his promotion and removal to Christiania, by Mr. Grewe and Mr. Cole.

Mr. Thomas, the Manager of the Alten Copper Mining Works, and a pastor, a Professor Lœstadius, an eminent botanist, are, I believe, the principal patrons of science at Alten.

Christiania, N. lat. 59° 54′ 1″, long. 10° 45′ 0″ east.
Alten, N. lat. 69° 58′ 3″ ±, long. 23° ± east.

Observations upon the Meteorological Observations for 1846 *and* 1847 *from Alten in Lapland, in a Letter from* Mr. J. F. COLE *to* Dr. LEE.

London, July 22, 1848.

SIR,—According to your desire I have examined the Alten Meteorological Observations for 1846 and 1847, which you have recently received from my former colleague, Mr. Grewe, and I have derived much pleasure from their inspection.

* See the Report of the Association for 1847, Transactions of the Sections, p. 33.

I find that several blanks occur in the course of the observations; also that the half-hourly observations on the 21st of the month are entirely discontinued. All this is not to be wondered at, since Mr. Grewe is now without any scientific assistant; and allowing for all the accidents of health and occupation, I consider that this gentleman deserves great praise for his diligence and perseverance in carrying on the observations as he has done. The Alten Meteorological Observations for 1843, 1844 and 1845 do not contain a single blank, as Mr. Grewe and I made it a point to endeavour to obtain three years' observations complete, so as to serve as a basis in comparing any observations that had been made at Alten before that time, or that might be made hereafter, and also to serve in comparing observations with any other part of the world. As those observations have been presented by you to the British Association, I have no doubt that they will prove highly interesting in assisting persons in their endeavours to find out meteorological laws or in following out any theories that meteorologists may advance.

The observations for 1846 and 1847, now forwarded by Mr. Grewe, and which you intend to present to the British Association, will prove interesting in consequence of what has already been done.

These observations show, that the mean of the barometer for 1846 was 755·8432 millim. or 29·75755 Engl. inch., and for 1847, 755·9854 millim. or 29·76315 Engl. inch.

The mean of the thermometer for 1846 was +1·667 Centig. or +35°·0006 Fahr., and for 1847, +2·594 Centig. or +36°·6692 Fahr.

The mean fall of rain per day was, for 1846, 1·266 millim. or 0·04984 Engl. inch., and for 1847, 1·186 millim. or 0·04669 Engl. inch.

The mean force of the wind was, for 1846, =1·611, and for 1847, =1·974 (according to the scale of forces adopted at Alten, viz. 1 = *almost calm* and 10 = *hurricane*; these means will fall between *almost calm* and *gentle breeze*).

The mean proportion of clear sky for 1846 was 2·502 parts, and for 1847, 2·796 parts (the sky is supposed to be divided into eight parts).

The highest range of the barometer for 1846 was 772·80 millim. or 30·42514 Engl. inch., and the lowest range was 733·62 millim. or 28·88262 Engl. inch., being a total range for 1846 of 39·18 millim. or 1·54252 Engl. inch.

The highest range of the barometer for 1847 was 778·10 millim. or 30·63380 Engl. inch., and the lowest range was 721·40 millim. or 28·40152 Engl. inch., being a total range for 1847 of 56·70 millim. or 2·23228 Engl. inch.

The highest range of the thermometer for 1846 was +28°·5 Centig. or +83°·3 Fahr., and the lowest range was −26°·0 Centig. or −14°·8 Fahr., being a total range for 1846 of 54°·5 Centig. or 98°·1 Fahr.

The highest range of the thermometer for 1847 was +29°·3 Centig. or +84°·74 Fahr., and the lowest range was −19°·5 Centig. or −3°·10 Fahr., being a total range for 1847 of 48°·8 Centig. or 87°·84 Fahr.

From the foregoing it will be seen that 1847 was much warmer than 1846, and that the mean height of the barometer was greater in 1847 than in 1846.

The total oscillation of the barometer was much greater in 1847 than in 1846, but the reverse was the case with the thermometer.

The atmosphere was drier, the wind was rather more powerful, and the sky was clearer in 1847 than in 1846.

I feel grateful that my humble labours, or rather amusements, and those of my excellent friend Mr. Grewe, have been deemed by you worthy of being introduced to the notice of the British Association of Science, and I beg to subscribe myself,

Sir,
Your obedient and humble Servant,
(Signed) JOHN FRANCIS COLE.

To John Lee, Esq., LL.D., &c.
Hartwell.

On two cases of uncommon Atmospheric Refraction. *By* MATTHEW MOGGRIDGE.

About midday on the 27th of January last we saw a schooner which appeared erect and resting on the top of the high sand-hill east of the mouth of the Neath

River, the whole of her hull being visible. As we passed on the image retained its position for some time, but vanished when we came to a turn of the road.

On arriving at a point where I could look down the river, I saw within about 150 yards of the sand-hill above referred to a schooner lying dry, which was evidently the vessel we had previously observed. She was much out of the proper channel, but had gone ashore by accident and remained there many weeks. The top of her masts was below the level of the sand-hill, so that her picture was thrown up more than the height of her masts.

The weather was cold, with a strong north-easterly wind and a bright sun; the schooner lying under the sand-hill, protected from the wind and in the full sunshine, which was powerful for the season. Two very different conditions therefore obtained in the atmosphere at that place; the air immediately surrounding the vessel being warmed by the sun, not under the influence of the wind, and probably charged with vapour evaporating from the wet sand; while the air above the level of the sand-hill was rapidly changed by the keen, frosty wind, and must have been of a very different temperature and density.

The other phænomenon to which I would direct attention occurred about nineteen years ago, and was witnessed by many most respectable parties, among others by the then vicar of Swansea, the late Dr. Hewson. The whole promontory of the Mumbles was seen reflected in the sky, so that at the same time the true image and the counterfeit were visible. There was a width of sky seen between the two of a breadth about equal to the height of the Mumble rocks, and the refracted image was a correct copy of that below, except that the perpendicular objects—as the lighthouse—were somewhat too tall, and became still more so before the disappearance of the illusive image, which was observed during about ten minutes.

Observations accompanying Wind and Current Charts of the North Atlantic. By Lieut. Maury, *U.S. Navy.*

[A Letter addressed to Prof. H. D. Rogers, by whom it was communicated to the Association.]

National Observatory, Washington, July 10, 1848.

These charts are offered not for what they are, but for what they may be. They are a mere first attempt, a rough beginning, incomplete and faulty, by reason of the very defective materials used in their construction. They are compiled from abstracts of old sea logs kept without order, system or arrangement. Some are without record as to current, temperature or variation; and others are faulty in many respects. But it was found necessary to make a *beginning* in order to attract the attention of navigators to the subject, and so procure labourers for the field; and this these charts have succeeded in doing, in this country at least.

Every navigator who will apply, is furnished gratis with a set of them and with a blank form, for recording results of the requisite observations. And though but a few weeks have elapsed since the publication of these charts, such has been the eagerness of navigators to procure each his copy, and such their readiness to contribute the requisite data for a more complete set, that fleets of ships are now engaged in all parts of the world (as they go to and from across the sea), in making and recording all—by a prescribed form—the necessary observations.

I have secured the co-operation both of the military and commercial marine of the United States, and before the end of the year, probably, not less than a thousand vessels will be collecting materials for the completion of these charts. Could the vessels of Great Britain be engaged in like manner, the value of the results would be greatly enhanced, because then we should probably have vessels enough engaged to afford synchronous observations for the space of a year, or longer, should it be desired, of the winds, currents, temperature of the ocean, &c. in all parts of the world.

The plan is, to construct similar charts of the three great oceans, to lay down the tracks of all the vessels engaged, in colours according to the season. Thus the tracks in winter will be all black; those in spring, green; in the summer, red; in the autumn, blue. Each track has marked on it, in such a manner as to show at once the daily experience of the navigator who made it, the winds, currents, temperature of the water, variation of the compass, &c.; thus placing at a glance before

each one, the combined experience of all who have sailed before him over the same part of the ocean.

To illustrate the importance of this undertaking, I may be excused for alluding to some of the practical results already obtained.

In consequence of the better knowledge afforded by this chart with regard to the winds in the North Atlantic Ocean, the average passage from the ports of the United States to the Equator (and consequently to all ports the way to which leads across the Equator) has been shortened several days. I have the tracks of four vessels which have been to Rio de Janeiro in Brazil, by the new route proposed on this chart. They have invariably made shorter passages than vessels sailing at the same time by the old route. The average passage by the old route to the line, is forty-one days; the mean of the four which have tried the new route is thirty-one days, the shortest being twenty-four days, the quickest of the season, and the longest thirty-nine days.

The information already collected has enabled me to strike out numerous *vigias* and fabulous dangers which deface our best general charts of the ocean, and which greatly increase the sources of anxiety which at all times surround the navigator. The positions of these *vigias* are laid down on the chart as doubtful, and when the ship is in the vicinity of any of them, it is a sleepless time with her master. I have the tracks of several hundred vessels which pass over and within 5° of some of these *vigias*, so that, if they were in existence, they certainly would have been seen by one or more. But they are not mentioned in the log, and it may therefore be fairly concluded that they do not exist. At the proper time I shall publish a list of *vigias* which these charts show ought to be erased.

The grouping together such a mass of facts in the manner proposed, will lead to many collateral, highly interesting and valuable results. Take as an example what is shown on the charts before you. If you will examine sheet No. 3, you will see that the trade-winds between the parallels of 5° and 10° N. from the coast of Africa nearly to the middle of the Atlantic, lose their *trade* character and become the baffling, variable airs known to sailors as the *doldrums*, whereas between the same parallels (sheet No. 2) on the American side, they blow with great regularity from the northward and eastward. In the former case, the sun shining upon the plains and deserts of Africa rarefies the air to *windward*, and this calls upon the winds of the sea to return and restore the equilibrium. In the latter case, the sun shining upon the plains of South America heats the air to *leeward*, and causes the trade-winds to hasten on and restore the equilibrium. In the one case the rarefaction takes place to windward, in the other to leeward, and the effect produced is clearly indicated by the chart, and is precisely such as might be expected.

Again, examine the winds in the Gulf of Mexico, sheet No. 1. The prevailing winds here are from the southward and eastward, while between the same parallels (sheet No. 2) and upon the broad ocean, the prevailing winds are the N.E. trades. As soon as the effect is seen the cause becomes obvious. Is it not to be found in the action of the sun upon Texas and the States of Northern Mexico? There is an immense body of land in this direction, and the heat of the sun upon it causes the winds to set towards it from the Gulf of Mexico. What effect a day of rain or of clouds over this body of land has upon the winds off the Pacific coast of Tehuantepec and Central America, is one of the interesting results to be anticipated from the work before us.

But perhaps the most interesting result yet obtained—and the undertaking is but just commenced—is the discovery within the limits of the N.E. trades in the Atlantic, of a region in which the prevailing winds are from the southward and westward.

This region is limited in extent, and is somewhat in the shape of a wedge, with its base towards the coast of Africa between the Equator and 10° N. It extends from long. 10° W. to about 25° W., being bounded by the Equator for one side, and by a line drawn from lat. 10° N. long. 10° W. to lat. 5° N. long. 25° W. on the other. How the case may be to the south of the Equator, I am not prepared to say. But to the north of it, I have discussed 2292 independent observations made within the above-described region by different vessels on their voyages across it. Included among these observations, calms were encountered on 246 occasions, leaving 2046

observations upon the winds. Of these, the winds were found from the northward and eastward (the regular trade quarter) .... 442 times.

From the S. and E.	 408	„
„ „ S. and W.	 951	„
„ „ N. and W.	 245	„

The law which governs the trade-winds is here reversed: they blow from the opposite quarter. And the natural tendency of winds cannot be so suddenly and completely reversed without creating violent atmospherical disturbances. Accordingly, the facts show this region to be one of violent squalls, sudden gusts of wind, of thunder-storms, heavy rains, lightning, baffling airs and calms. It is known to sailors as the region for the equatorial '*doldrums*.'

To the westward of this region and between the same parallels, the winds again assume their normal direction, and prevail from the eastward.

It is not a little singular that vessels bound from any of the ports in the United States to Brazil, should cross the Atlantic nearly twice, and if they be bound round the Cape of Good Hope they cross it three times. The usual route of vessels bound from the United States to any port beyond the Equator is to steer almost an east course, many of them making the Canaries, and most of them Cape de Verde islands, as the chart will show. They then shape their course through this "doldrum" region and steer to the southward and westward for their port. Now the log-books in my possession show that southward-bound vessels in traversing this region may expect to encounter either head winds or calms about 1400 times out of 2292. The navigator would therefore have about two chances to one against a fair wind in this portion of the route.

To the west of this region and more directly in the straight line from the United States, the chart shows a blank space through which a straggling vessel passes only now and then. The chart indicates, and facts subsequently obtained show, that here the prevailing winds are more favourable than they are by the usual route, for a short passage to the Equator. The materials so far collected—and they are extensive—show that if a Rio bound vessel were to keep to the westward of 25°, the wager instead of being two to one against fair winds, would be three to one in favour of them. Between the meridians of 25° and 35° W. I have 800 observations extending from the Equator to 5° N. Of these,—

257	give the wind	from	N. and E.
366	„	„	S. and E.
102	„	„	S. and W.
30	„	„	N. and W.
and 45 calms.			

Hence it appears that in this region there are three calms and four S.W. winds to the east of long. 25°, to one calm and one S.W. wind to the west of that meridian. The wager against head winds and calms by this route, and in this part of it, would be one head wind for three fair ones, instead of two head winds for one fair one by the usual route. Moreover the distance by the new route is nearly 1000 miles less than by the old.

It may be asked, why has not a route which is so obviously better and more direct been tried before? The answer is ready; sailors more than any other class of men are prone to follow in the wake of their predecessors. They know and feel that the experience of any one of them as to winds and weather at sea is at the best very limited. It is confined to the spot where he may be; they are therefore prone to follow their guide-books. Cook went that way in 1776. Hydrographers put his track on their chart as a guide, the next to come after him took the same track, and each has continued to follow the other.

Meteorological Observations at Huggate for 1847. *By* Thos. Rankin.

Greatest degree of cold, therm. 16°, March 11th; 7° colder than last year. Hottest day 78°, July 14th; 5° less than last year. Greatest range of therm. for any given day 33°, July 3rd; least range 1°, Jan. 8th. Greatest range for any given

month 43°, March; least range 20°, December. Range for the whole year 4° greater than 1846.

Maximum of barometer 30·33, March 4th; ·20 less than 1846. Minimum 27·80, December 6th; ·52 less than 1846. Greatest range for any month 2·05, December; ·65 greater than 1846. Least range ·12, February; ·33 less than 1846. Range for the year ·59 greater than 1846.

Rain fallen 30·232 inches; 4·838 inches less than 1846. Least rain in any month 1·000 inch, February; most, 5·375 inches, May.

Winds: east 2 days, west 45, north 2, south 1, north-east 15, north-west 27, south-east 8, south-west 39.

Weather: clear 127 days, rain 48, frost 23, snow 18, mist 18, thunder 3.

The author adds remarks on auroræ, characteristic clouds, and other phænomena.

Remarkable Tide in the British Channel, Friday, July 7, 1848, *as it appeared at Lyme Regis, Dorset. By* George Roberts.

Weather warm and calm. Dead neap tides. Fine for twenty-four hours before the phænomenon. About two hours and a half before the phænomenon, at 1½ A.M., it blew hard for ten minutes. The wind before and after this gust was gentle, and had gone round to all points of the compass. At dead low water, or perhaps just after the water had begun to flow at 4 A.M., the tide began to run into the Cobb, so that a boat rowed with two oars could not make head against it, but was carried along with it. My informant estimates the height of the water to have been about six or seven feet, and that it took eight minutes to flow in, or at most ten minutes, and the same time to flow out. Then when out it began to flow in again, and so continued till eight o'clock, a space of four hours, when the sea was quite calm, and so continued all the day. The same was experienced at Dartmouth and Portland. Some of the sailors said it was a bore; others that it was caused by thunder-weather; some said there had been an earthquake in the ocean: some sailors say the tide ran ten knots an hour *.

Note on 'Shooting Stars' seen August 10, *at Armagh. By the* Rev. T. R. Robinson, *D.D.*

Though last night was mostly cloudy here we saw a good many 'shooting stars.' From 12^h to $12^h\ 45^m$ thirty were seen through a thick covering of the stratus family; their light was bluish-white, and most had long red trains. Towards morning it cleared, and from $1^h\ 41^m$ to $2^h\ 41^m$ three of us counted 117; but as two used deep spectacles in which the margin of the field of view must be indistinct, it is probable that many of the smaller were missed. Many of them were large and brilliant, and with few exceptions their motion was directed to a point which I estimate to be near η Ophiuchi. It is remarkable that nearly five-sixths of the whole were north of the prime vertical. Several seemed to explode in their course, and so decidedly that we actually listened for explosions. None were however heard, though the night was perfectly still.

In the earlier part of the evening aurora was seen in the N.E., and it must have been rather intense, or it could not have been visible in the moonlight.

On certain Effects produced on Sound by the rapid motion of the observer. By J. Scott Russell, *F.R.S. Ed.*

Until the production of the very high velocities now given to railway trains, no

* In Mr. Roberts's Collection of Historical Matter respecting Lyme Regis, are three entries made by old clerk Read as follows:—

"May 31, 1759: the sea flowed three times in one hour.

"Aug. 18, 1797: the sea flowed three times in one hour, attended with lightning.

"Jan. 26, 1799: the sea as above about 4 o'clock A.M."

Upon a summer's day about 1813 something similar took place. Mr. Roberts asks whether the *Seiches* of the Swiss lakes are referrible to the same cause as these movements of the water of our British Channel.

opportunities have existed of observing any phænomena in which the velocity of the observer has been sufficient to affect the character of sounds. The author having had occasion to make observations on railway trains moving at high velocities, has been led to notice some very curious effects in sounds heard at 50 and 60 miles an hour. These effects are not heard by an observer who is stationary. He found that the sound of the whistle of an engine stationary on the line was heard by a passenger in a rapid train to sound a different note—in a different key from that in which it was heard by the person standing beside it. The same was true of all sounds. The passenger in rapid motion heard them in a different key, which might be either louder or lower in pitch than the true or stationary sound. The explanation of this was given as follows. The pitch of a musical sound is determined by the number of vibrations which reach the ear in a second of time—32 vibrations per second of an organ-pipe give the note C, and a greater or less number give a more acute sound or one more grave. These vibrations move with a velocity of 1024 feet per second nearly. If an observer in a railway train move at the rate of 56 miles an hour towards a sounding body, he will meet a greater number of undulations in a second of time than if at rest, in the proportion which his movement bears to the velocity of sound; but if he move away from the sounding body he will meet a smaller number in that proportion. In the former case he will hear the sound a semitone higher, and in the second a semitone lower than the observer at rest. In the case of two trains meeting at this velocity, the one containing the sounding body and the other the observer, the effect is doubled in amount. Before the trains meet the sound is heard two semitones too high, and after they pass two semitones too low—being a difference of a major third. There were next explained the various effects which the noises of a train produced on the ears of passengers at high velocities. The reflected sounds of a train, from surfaces like those of bridges across the line, were at ordinary velocities sent back to the ear changed by less than a tone, so as to cause a harsh discord, which was an element of the unpleasant effect on the ear, of passing a bridge. In a tunnel also the sounds reflected from any irregularities in the front of the train or behind it were discords to the sounds of the train heard directly. He showed however that at speeds of 112 miles an hour these sounds might be those of a harmony with each other and become agreeable, for the sounds reflected in opposite directions would have the interval of a major third.

On the Lengths and Velocities of Waves. By Capt. STANLEY, *R.N.* (*Extract from a Letter to the* Rev. Dr. Whewell.)

The method I adopted for the determination of the length and speed of the sea, was to veer a spar astern by the marked lead-line, when the ship was going dead before the wind and sea, until the spar was on the crest of one wave while the ship's stern was on the crest of the preceding one. After a few trials, I found that when the sea was at all regular I could obtain this distance within two or three fathoms when the length of wave was fifty.

In order to ascertain the speed of the sea, the time was noted when the crest of the advancing wave passed the spar astern, and also the time when it reached the ship; and by taking a number of observations, I have every reason to believe we have obtained a result not very far from the truth. The officer noting the time in all these observations having only to register the indications of the watch when the observer called stop, had no bias to induce him to make the differences more regular.

For measuring the height of the waves, I adopted a plan recommended to me by Mrs. Somerville, which I have tried for ten years with great success. When the ship is in the trough of the sea, the person observing ascends the rigging until he can just see the crest of the coming wave on with the horizon, and the height of his eye above the ship's water-line will give a very fair measure of the difference of level between the crest and hollow of a sea. Of course in all these observations the mean of a great many have been taken, for even when the sea is most regular apparently there is a change in the height of the individual waves.

I regret that we have had so few opportunities of making these observations, but it is only under very favourable circumstances, when the ship is going directly before both wind and sea, that they can be made with any chance of success; but

I mean to lose no opportunity of obtaining more. The following is a summary of the observations :—

Date.	Number of observations.	Force of wind.	Speed of ship.	Height of wave.	Length of wave.	Time of wave passing from spar to stern.	Speed of sea deduced.	Remarks.
1847.			knots.	feet.	fath.	seconds.	knots.	
April 21.	...	5	7·2	22	55	10·0	27	Ship before the wind, with a heavy following sea.
... 23.	8	5	6·0	20	43	8·0	24·5	Ditto.
... 24.	6	4	6·0	20	50	10·0	24·0	Ditto.
... 25.	9	4	5·0	...	35 to 40	7·8	22·1	Sea irregular.
... 26.	...	4	6·0	...	33	7·4	22·1	Heavy following sea.
May 2.	6	(4·5)	7·0	22	57	10·4	26·2	Sea irregular. Observation not very good in consequence.
... 3.	7	5	7·8	17	35	8·9	22	Wind and sea a little on Port Quarter.

Note.—The numbers denoting the strength of the wind are those used by Admiral Beaufort.

On the Fall of Rain on the Table-land of Uttree Mullay, Travancore, during the year 1846, *from observations made by* General Cullen, *Resident in Travancore. By* Lieut.-Colonel SYKES, *V.P.R.S.*

At the Meeting of the British Association at Southampton I communicated to the Physical Section some meteorological records of General Cullen made at certain stations in the south of India. The results exhibited singular discrepancies in the fall of rain at the several localities, particularly at Cape Comorin, although the differences of temperatures were unimportant at stations not differing greatly in their level above the sea or in their latitude. The most remarkable feature was the small quantity of rain at Cape Comorin and Vaurioor at the extremity of the peninsula, amounting only from 18 to 25¾ inches in the years 1841, 1842 and 1843, while from 100 to 131 inches fell at places on the Malabar coast, and about 290 inches fell on the table-land of Uttree Mullay, not far in the interior. I suggested to General Cullen an examination of local physical circumstances, with a view to account for the variations. In a letter in reply, dated the 6th of January last, from Trevandrum, General Cullen said that the General Tables were ready for 1844, 1845 and 1846, but that public business had left him without leisure to comment on them, or to complete the barometrical sections which he contemplated; and all that he could then do was to transmit to me a continuation of the rain and temperature observations for 1846 on the table-land of Uttree Mullay at 4600 feet above the level of the sea, adding in an abstract, in parallel columns, the comparative fall of rain at Trevandrum and Quilon. For a future communication therefore is reserved General Cullen's views of the question submitted to him, and the present notice is limited to his daily observations of the fall of rain and the temperature at Uttree Mullay. The fall of rain was recorded twice daily, at 6 A.M. and 6 P.M., and the temperature thrice daily, 6 A.M., 2 P.M. and 6 P.M. In 1844–45 the fall of rain had been 290 inches: in 1846 it was only 235·8 inches. It has been formerly stated that Uttree Mullay is under the influence of both monsoons. Rain fell in every month in the year, although the months of February and March may almost be considered exceptions; for in the former month rain fell only twice to the amount of 0·45 of an inch, and in the latter month on five occasions, but to the amount only of 0·72 of an inch. The greatest monthly fall of ra.n was in the month of June, 51 inches, in the S.W. monsoon, and the next greatest fall in October, in the N.E. monsoon, 38·25 inch. In the months of May, June, July and August the S.W. monsoon may be considered to have prevailed, and 143 inches of rain fell. A *comparative*

cessation occurs in September, when the monthly minimum of 22 inches in August of the S.W. monsoon is reduced to 7·3 inches. The N.E. monsoon commences in October with 38·2 inches, gradually diminishing in amount until January, the last month of the N.E. monsoon, when the fall in 1846 was reduced to 4·6 inches, the whole fall in the four months of the N.E. monsoon being about 75 inches. February, March and April are the precursors of the S.W. monsoon, and September intermediate between the termination of the S.W. monsoon and the commencement of the N.E. monsoon. The average annual fall of rain upon this elevated table-land during the day and during the night does not appear to differ materially, although it is somewhat in excess at night, being 123·1 inches to 112·7 inches during the day. The excess at night however does not hold good through all the months. In May there were 17·1 inches by night and 19·7 inches by day; in August 8·8 inches by night and 13·3 inches by day; and in September 1·9 inch by night and 5·6 inches by day. Neither is there any uniformity in the fall of rain in the same months of the two monsoons in successive years, but the maximum monthly fall will be found in one of the four months of the respective monsoons, although it may occur in May in one year and in August in the following, or in October of one year and in December of the next in the N.E. monsoon. While 235·8 inches fell in 1846 at Uttree Mullay, 69·9 inches only fell at Trevandrum, and 74·7 inches at Quilon; in May 11·4 inches fell at Trevandrum, but 22·7 inches at Quilon on the coast; in October the case was reversed, 17·5 inches fell at Trevandrum and only 9·4 inches at Quilon. In 1844–45 an instance was given of a fall of 9 inches of rain in one day, on the 10th of October, at Uttree Mullay; and on the 26th of November of 7·35 inches. Nothing similar to the first fall occurred in 1846, the greatest being 7·6 inches on the 25th of May; and there are three instances of a daily fall of nearly 7 inches on the 24th of April, 12th of July, and the 13th of October. The monthly *mean* temperature at Uttree Mullay, at 6 A.M., varied only from 57°·5 in January to 65°·75 in August and September; at 2 P.M. from 66°·25 in June to 73°·75 in April; and at 6 P.M. from 62°·25 to 67° in the months of April and July. The annual mean at the respective hours was 63°, 69° and 65°·16, and the mean of the whole observations 65°·66. The extreme annual range of the thermometer was from 55·5 on the 31st of January and 15th of December to 78° on the 6th, 21st and 22nd of April, so that the extremes differed from the mean by only 10°·16 minus and 12°·34 plus. With such limited general results it would be superfluous to particularize monthly variations of temperature.

Abstract.

Months in 1846.	Uttree Mullay.					
	Rain.			Thermometer.		
	Day.	Night.	Total.	6 A.M.	2 P.M.	6 P.M.
	inches.	inches.	inches.			
January	3·050	1·600	4·650	57½	66¾	62¼
February	0·400	0·050	0·450	60	68¾	64
March	0·550	0·175	0·725	62¾	71¼	64¾
April	4·050	5·550	9·600	64½	73¾	67
May	17·100	19·700	36·500	64¾	72	66¾
June	28·700	23·300	51·050	64¼	66¼	64¾
July	17·400	14·675	33·325	63	68	67
August	8 850	13·375	22·125	65¾	68¼	66¼
September	1·925	5·600	7·325	65¾	70¼	66½
October	23·750	14·200	38·250	64½	68	64¼
November	10·325	11·350	21·675	63½	68¼	65
December	7·100	3·200	10·200	60	66¾	63¾
Grand total	123·200	112·775	235·875	63	69	65⅛
				Mean 65⅔		

Rain in 1846.

1846.	On Uttree Mullay.	Trevandrum.	Quilon.
	inches.	inches.	inches.
January	4·650	0·100	0·000
February............	0·450	•	
March..............	0·725	1·075	2·900
April	9·600	4·025	1·600
May	36·500	11·425	22·700
June	51·050	17·750	17·650
July	33·325	6·925	10·550
August	22·125	3·675	3·800
September	7·325	0·750	1·300
October	38·250	17·500	9·400
November	21·675	4·400	4·755
December	10·200	2·300	0·100
Total	235·875	69·925	74·755

On Atmospheric Disturbances, and on a remarkable Storm at Bombay on the 6th of April 1848. *By* Lieut-Colonel SYKES, *V.P.R.S.*

Numerous are the expressions of surprise in England at the extraordinary character of the meteorological phænomena since last year. Mr. Glaisher of the Royal Observatory, Greenwich, in remarks on the weather during the quarter ending the 31st March last, says, "The weather during the past quarter has been remarkable in many respects. The daily temperature has been *above* the average; yet there has been exceedingly cold weather between the 20th and 26th January; and the temperature of the preceding quarter was in excess to the amount of 3°·4. The mean temperature of evaporation and of the dew-point above the average; the mean weight of water in a cubic foot of air of the same value as for the preceding six years. The quantity required to complete saturation 0·47 of a grain; the average for the preceding six years being 0·36 of a grain. The barometer was 0·132 below the average of seven years and the readings remarkable; and the great fluctuations in the readings appear to have been general, and differing from any period since 1800." A sympeisometer in my house in Albion Street, Hyde Park, in December last, fell 1 inch in twenty-four hours *without a storm*; and I have frequent records of rain without the sympeisometer being moved. A correspondent of the *Times*, in a letter dated Bermondsey, 7th Dec. 1847, speaks of the sudden and extraordinary changes in the atmosphere, and adds that his barometer, which stood at 29·92 at 11 P.M. Sunday, 5th Dec., had on Monday the 6th, at 8 A.M., sunk to 28·92, a difference of 1·2 inch in nine hours; and at 12 o'clock Monday night of the 6th, it stood at 28·54; a difference of 1·38 inch in twenty-five hours, the air in that interval having been relieved of pressure at the rate of 326 lbs. on every square foot of superficial area. Magnetic instruments also have shown unusual disturbances. The fall of rain has been nearly double that of the preceding six years, and 2½ inches above the average since 1815. The range of a protected thermometer was from 71°·5 to 15°·7 or 55°·7; but a thermometer on the grass at Durham fell below zero; and on the 12th of July preceding it stood at 87 in the shade in London.

In the north of Scotland in January, correspondents wrote, "We have had the extremes of weather." Strange as it may appear, two gentlemen, Mr. Stericker and Mr. Whilburn, were frozen to death in September in Invernesshire. Short intense frosts and rapid thaws characterized the winter in England. At Madrid, in January, the cold was intense, yet in Lancashire there were some fresh sprigs of hawthorn 3 inches in length, and leaves of the honeysuckle open; and the primroses and foxgloves were as much advanced as if it had been the month of March; and the wild fowl, which usually pass in November, did not pass until the middle of December.

On the 12th of December, near Penzance, four whirlwinds occurred, unroofing houses and overturning furze and turf-ricks, and carrying with them great quan-

tities of snow, tiles, slates, &c. They were like inverted cones of vapour,—revolved swiftly on their axes, and coursed along at the rate of 20 miles an hour. Rotatory whirlwinds in the midst of winter, which are only seen in tropical climates in the most intensely hot weather, seem remarkable phænomena. Amongst the other physical phænomena in accord with the tumults amongst men, was that of the eruption of Vesuvius, which during my stay in Naples the last days of March and beginning of April in the present year, was pouring out four fiery streams of lava amidst explosions.

But meteorological anomalies were not confined to Europe; and if we look to the records of India for the last year, we shall find that observers have had equal cause for surprise and comment.

"Tuesday, February 16.—From the Bombay papers it appears that they have actually had ice at Poona."—*From Bengal Hurkaru.*

This was almost a miracle, for such a circumstance had never been recorded before.

"The cold weather, which *so suddenly* and *unexpectedly* returned upon us, has now taken what we may consider its final departure for the season."—*Calcutta Hurkaru*, Feb. 18, 1847.

"There had been a very severe storm in the northern hills—at Simla snow lay three feet deep and all the high grounds about the Dehra Dhoon were covered."—*Bombay Times*, May 2, 1847.

From the Deccan the accounts, on the 22nd of February, 1847, state,—"We have had rain all over the Deccan from the south-east, strange at this season; the rain was also heavy and continuous, quite monsoon weather."

On the 15th of November, 1847, the editor of the *Bombay Times*, Dr. Buist, a distinguished meteorologist, has the following remarks in his paper respecting the great anomaly of a large fall of rain in November, a month of the dry season:—

"November has opened as if another monsoon were just commencing. On Saturday and Sunday the thermometer rose on the Esplanade as high as 90°; in the coolest and most airy buildings in Colaba it stood at 87°; the wind dry and blowing strong till past noon from the north-east. On Sunday evening there was some thunder and a few drops of rain, and on Monday a stiff breeze blew about sunset from nearly east, and the sky looked most threatening. All yesterday it was close, hot and muggy, a slight shower having fallen in the morning—thermometer 85°, the barometer slightly down."—*Bombay Times*, Nov. 3.

"We mentioned in our last that we had had some thunder with a threatening of November showers: they have come in greater abundance than was expected. About midnight on Tuesday a very heavy fall of rain commenced and continued for a couple of hours, and all over the morning it looked thick and lowering. Little rain fell next night, but there were showers over the morning, and betwixt one and three on Thursday it rained heavily, and continued cloudy all the afternoon and evening. About ten o'clock a thick close rain commenced, with a bleak north-east wind: both have continued ever since. Yesterday was more like the middle of the monsoon than a day in clear and dry November. The thermometer, which on Sunday stood at from 85° to 90°, has all at once plumped down to betwixt 70° and 75°—*a change great and sudden enough to be very unpleasant to the feelings.* More than 3 inches of rain fell. The barometer has *all this while stood high, and made no sign*! The rains appear to have been general all along and below the Ghauts: the Mahabuleshwar range seems to have suffered severely. We have just heard of much mischief having been occasioned to the unstacked rice all over the island, and the damage must be general wherever grain crops are still in the field: all the low grounds are flooded, and the dry channels running torrents.

Fall of rain in the Fort during November.	in.
Up to 6 P.M. 1st Nov.	0·00
„ „ 2nd „	0·00
„ „ 3rd „	0·65
„ „ 4th „	0·06
„ „ 5th „	2·87
	3·58"

—*Ibid.* Nov. 6.

"The weather has taken this week *almost as sudden a change as it did last*, but on the present occasion fortunately it is in the right direction. The rain, which continued to pour in torrents till early on Saturday morning (upwards of two inches of rain fell during Friday night—making a total fall of *nearly six inches during November*), faired up on that day. We have now in fact fairly got into the cold season with all its nipping freshness: a coat is at no time unpleasant—blankets overnight indispensable. The thermometer ranges from 72° to 79°. So thoroughly drenched have been the paddy-fields that we have still two or three inches of water all over the surface of the flatter portions of the ground."—*Ibid.* Nov. 10.

"The weather has now set in steady and cool, the thermometer ranging from 70° to 79°—water in exposed situations falling as low as 65° overnight. The sea and land winds are fresh and strong."—*Ibid.* Nov. 13.

"From out stations we gather the following items:—

"SURAT.—A letter from Surat informs us of an unexpected flood which had occurred on the Taptee, which had commenced at noon on the 7th, the river continuing to rise for about twenty hours, when it had attained near the town a depth of fifteen feet above its previous level. The cut connecting the river from Burcutcha with the sea relieved the flood and saved the city from desolation similar to the visitations of this sort which formerly afflicted it in cases of freshes in the river. Several pattimars had been driven from their anchorages; some cattle had been drowned, and three carts on their way from Broach were said to have been carried away. A heavy fall of rain in the Malwa district was supposed to have been the cause of the flood. The rains which prevailed here betwixt the 3rd and 5th must in fact have been very general: the commencement of them at the former date on the Coromandel coast is mentioned by our Madras contemporaries: at Poona upwards of three inches of rain fell; and a heavy fall occurred at Belgaum; while all along the Ghauts the storm seems to have prevailed. *It is curious that at Poona more than twelve inches of rain have this year fallen in April and November—both falls in the fair season.*"—*Times*, November 13.

These notices of atmospheric disturbances, which I could very considerably increase, I have thought to be suitable precursors of a notice of a remarkable storm in Bombay on the 6th of April last, in which the barometer rose instead of falling; the facts being supplied by the Magnetic Observatory, and the comments by that very zealous and able promoter of scientific research, Dr. Buist, LL.D., the Editor of the *Bombay Times*.

THE STORM OF THE 6TH OF APRIL 1848.

State of the Weather.

April 6th, 9 A.M. Nimbi, cirrocumuli and cirri throughout, except in the S.W., which is clear.

...... 10 A.M. Overcast by nimbi and cirrocumuli.

...... 11 A.M. Overcast by nimbi and cirrocumuli; a few breaks in the N.

...... 12 A.M. Nimbi scattered throughout.

...... 1 P.M. Nimbi in the horizon from N.E. to S.W. (by E.); masses of fleecy clouds scattered throughout the zenith.

...... 2 P.M. Nimbi scattered; clear in the S.W.

...... 3 P.M. Nimbi all round the horizon, and cirri in the S.W.; zenith clear.

...... 4 P.M. Nimbus and cumuli all round the horizon, very dense in the S.E.; zenith clear.

5 P.M. Nimbus; cumulostratus extending from N.E. to S.E.; cirri scattered throughout the whole of the sky.

6 P.M. Electrified cumuli extended from N. to S.E., and nimbi scattered throughout; masses of scud coming from the S. and W.

7 P.M. Nimbus and scud coming from the S.W. and forming into dense masses in the N.N.E. and S.E.; lightning at intervals of 5 min.

8 P.M. Densely overcast; thunder in continued peals, N. and E. of zenith; vivid lightning, flash after flash, from N. to S.W. (by M.); rain in large drops since $7^h\ 30^m$.

9 P.M. Densely overcast; thunder and lightning increased, and in all

quarters. Drizzling rain, in large drops, has continued to fall since last observation.

April 6th, 10 P.M. Densely overcast; squalls of wind and rain; lightning flashing and thunder pealing in all quarters; at 9^h 20^m violent gusts of wind, which lasted 20 minutes.

...... 11 P.M. Densely overcast; drizzling rain—thunder and lightning still continuing.

April 7th, midnight. Overcast; rain falling in small drops; thunder and lightning decreasing.

...... 1 A.M. Overcast; no rain; lightning in the S. and S.W. at two seconds interval; the thunder has ceased.

...... 2 A.M. Do. do. do. do.

...... 3 A.M. Nimbi; stars faintly seen; lightning in the S. at intervals of 15 min.

...... 4 A.M. Nimbi; zenith clear; lightning in the N.W. horizon.

...... 5 A.M. Overcast; lightning in the N.E.; thunder in the N.

...... 6 A.M. Nimbi.

...... 7 A.M. Nimbi; fleecy clouds moving from the N.E.

...... 8 A.M. Nimbi; cirrocumuli in the zenith.

...... 9 A.M. Cirrostratus and cirrocumuli; many breaks in the zenith.

Abstract of Meteorological Observations from the Observatory Report, from 9 A.M. *April* 6, *to* 9 A.M. *April* 7, 1848.

Bombay, Magnetic Observatory, 8th April, 1848.

Days and hours.	Standard barometer corrected.	Air-thermometer.	Wet-bulb thermometer.	Pressure of moisture.	Humidity of air.	Wind.		Rain in inches.	Extent of cloudy sky.
						Direction.	Force in lbs.		
6th April, 9 A.M.	29·847	80·5	77·0	0·772	0·85	S.S.E.	0·05	...	5/8
...... 10 A.M.	29·857	85·4	77·0	0·818	0·90	S.S.W.	0·05	...	whole
...... 11 A.M.	29·861	87·6	78·0	0·833	0·89	W.N.W.	0·05	...	7/8
...... 12 A.M.	29·827	87·4	78·0	0·836	0·89	W.S.W.	0·16	...	7/8
...... 1 P.M.	29·782	89·2	79·0	0·858	0·89	W.S.W.	0·21	...	1/2
...... 2 P.M.	29·745	89·0	79·0	0·860	0·89	W.S.W.	0·10	...	3/8
...... 3 P.M.	29·701	88·0	79·0	0·871	0·90	W.S.W.	0·36	...	whole
...... 4 P.M.	29·707	86·0	79·1	0·897	0·92	W.S.W.	0·42		
...... 5 P.M.	29·727	85·0	79·0	0·904	0·92	W.S.W.	0·36	...	3/4
...... 6 P.M.	29·764	83·5	79·0	0·921	0·95	S.W.	0·46	...	3/4
...... 7 P.M.	29·799	82·7	77·0	0·847	0·93	S.	1·00	...	5/8
...... 8 P.M.	29·798	79·5	77·5	0·902	0·98	S.	1·25	0·01	whole
...... 9 P.M.	29·830	77·5	75·0	0·826	0·97	N.E.	1·20	0·01	whole
...... 10 P.M.	29·920	69·3	70·0	0·734	1·00	E.N.E.	2·10	0·34	whole
...... 11 P.M.	29·857	71·2	70·0	0·713	0·98	N.N.E.	1·78	0·08	whole
7th April, midnight	29·789	72·0	70·0	0·704	0·97	E.N.E.	1·52	0·03	whole
...... 1 A.M.	29·784	73·4	72·0	0·760	0·98	S.E.	0·10	...	whole
...... 2 A.M.	29·761	75·0	72·5	0·759	0·97	S.S.E.	1·04	...	whole
...... 3 A.M.	29·766	75·8	72·0	0·733	0·95	S.E.	0·94	...	7/8
...... 4 A.M.	29·777	75·5	72·5	0·755	0·96	S.S.E.	0·62	...	3/4
...... 5 A.M.	29·779	75·7	73·0	0·771	0·96	S.	0·62	...	whole
...... 6 A.M.	29·799	77·0	73·0	0·757	0·95	S.	0·52	...	whole
...... 7 A.M.	29·827	78·5	74·4	0·793	0·95	S.	0·52	...	whole
...... 8 A.M.	29·872	80·4	75·2	0·803	0·93	S.	0·36	...	7/8
...... 9 A.M.	29·876	81·3	74·0	0·747	0·90	S.S.E.	0·05	...	7/8
Total fall of rain								0·47	

NOTE.—*Remarks on the Thunder and Lightning Storm of the 6th of April* 1848.

At 6 o'clock in the evening the appearance of the sky in the N. and E. was very remarkable:—Cumuli, cumulostrati, and scud, were cumulating in the N. and across the E. to S.E., rising to an elevation of nearly 60° from the horizon. Upon

these were masses of nimbi that came floating from the S.W., from which quarter the wind was blowing with a force of 046 lbs.; deep mutterings of thunder were heard: and lightning was seen to flash vividly, upwards, from the summit of the clouds along their whole breadth, or from N. to S.E.

At 6^h 45^m.—The wind changed from S.W. to S., and the clouds in the N.E. and E. became more threatening in their appearance; and at this period the lightning, which was of a brilliant purple colour and very vivid, flashed continually; each flash was followed by loud peals of thunder. The character of the lightning in this second appearance was more terrific than before, as every flash was vertical, and several times these vertical streams were visible simultaneously, and as many as five were distinctly counted, at irregular distances from each other, varying from 2° to 12°.

At 7^h 30^m.—Rain began to fall in large drops; the thunder and lightning increasing till 9^h 00^m, when the wind moved round to N.E. (by E.), and the whole of the sky presented one dark mass of nimbi; the thunder and lightning still continuing.

At 9^h 15^m.—A gale of wind came on from the N.E. with a force of nearly 6 lbs.; and at 9^h 20^m it reached its maximum force, which was nearly 9 lbs.; the whole time which it lasted was about 20 minutes. During this gale the *barometer rose* (instead of falling) to 29·920, or about 0·1 of an inch above its true level; when the gale was over, *it rapidly descended* to nearly its former readings, as will be seen from the accompanying observations of the meteorological instruments; at 10^h 40^m the wind became due north.

The thunder and lightning continued, but at greater intervals; and the rain falling till midnight, at which time the rain ceased. But the thunder and lightning may be said to have continued all night.

From the peculiar rise of the barometer during the worst part of the gale, it is supposed that a heavy storm was felt somewhere on the mainland to the E.N.E.; and the gale which we felt was only the momentum that the air received when rushing towards that place; it is also possible that the storm was raging there very heavily at sunset. During the worst part of the gale the temperature suddenly *decreased* 10°.

It may be here remarked, that during the continuance of the gale, which was felt along the coast, and very slightly in Bombay, in April last year, our magnetic instruments remained *perfectly steady*; but as soon as the gale passed away, they became disturbed, and continued so for 54 hours. This year precisely the same remarkable phænomena have taken place, as during the whole time of the meteorological disturbance of the last few days they *remained steady*, but at 8 o'clock this morning they became disturbed (or the magnetic storm commenced), and continue so up to the present time.

The rising of the barometer with the storm and the falling after it; the magnetic instruments remaining quiescent during the storm, and being disturbed after it; and the sudden fall of temperature of 10°, are all sufficiently remarkable facts. Upon the above return Dr. Buist observes,—"The disclosures made are singular; the wind on the morning of the 6th blew from S.S.E., an unusual quarter; from this it swept round by S. and S.W. to N.N.W., and then moved back again to W.S.W., where it remained till evening. It then set first to S.W., and then veered round to S. From this it travelled round in an easterly direction to N.E., E.N.E., N.N.E., and so swept back by E. to S.,—having in the course of twenty-four hours twice swept round three-quarters of a circle and so swept back again, leaving the segment betwixt W.N.W. and N.E. untouched. At ten o'clock (P.M.), when the storm was at its wildest, the barometer *actually rose instead of falling*, and that by no less than about 00·08 above the level due to ten o'clock, interpolating from the readings of nine and eleven. The diurnal curve, indeed, is remarkable. On the 6th the mercury reached its maximum elevation at eleven A.M. instead of a quarter before ten—the average hour for maximum, and its afternoon minimum at three instead of a quarter past four; so that instead of six hours and a half, the usual time, there was less than four hours of an interval between the epochs of maxima and minima. These things are of very great importance as subjects of attention, considering the smallness and extreme inequality of our range. It attained its maximum at the proper hour, ten

P.M.—this, as already stated, being marked by a sudden jump of no less than eight hundredth parts of an inch above what was due. The epoch of morning minimum, again, was two o'clock, or two hours earlier than usual, the interval having been this much shortened. The return does not afford the morning maximum of the 7th, but the mercury continued steady till nearly nine o'clock, and would probably reach its turning-point at ten, giving an interval of no less than eight hours of time. The range betwixt the evening minimum and maximum on the 6th was ·219, or, if we subtract ·080 for the jump, ·139,—a high range for the season. At ten o'clock the air was saturated with moisture, the wet-bulb standing ·7 higher than the dry, the latter having *in two hours'* time tumbled down from 79° to 69°, and in the course of the ten hours having had a range of no less than 20°—a very unusual circumstance in Bombay. From the rise of the barometer, it was inferred at the observatory that a storm was raging on the mainland somewhere to the E.N.E. of us. *Just after the gale had ceased, the magnetic instruments began to be disturbed, and this is the third time the same thing has happened at the observatory on the back of a storm within little more than two years*—on the 4th of December 1845, and in April 1847 and 1848. On the first-named of these days there was a magnificent display of *Aurora* in the northern sky, and a great magnetic disturbance all over the world; on the last two occasions just named we have seen no account of any irregularities anywhere but at Bombay. Now that it has occurred so frequently as to call attention and forbid the idea of the coincidence being accidental, it will be interesting to learn from other observatories what has occurred, and to watch with extreme care whether these things always occur coincidently, or whether there are local laws at work here to stir the magnets after a storm at certain seasons only. The first notice of the subject we remember is that published by Mr. Orlebar in the *Bombay Courier* of December 1845; for the three preceding years the magnetometers were in general remarkable for their steadiness during tempests. On the evening of the 6th we had streams of electric fluid rushing like a handful of beads in rapid torrents to the ground; this beautiful and sublime appearance, only witnessed when the thunder-clouds are near us, has been frequently before described.

"Since writing the above we have been favoured with the following notice of the state of the weather at Nassick on the 6th and 7th. From this it will be seen that the conjecture of a storm having occurred to the north-eastward of us about sunset proves correct. It is unfortunate that Dr. Stuart should not have been possessed of a barometer or any other means of measuring pressure, or we should in this case have been able to trace the analogies or anomalies existing at the two localities. Nearly all the phænomena observable at Bombay betwixt nine and twelve were observed at Nassick betwixt five and eight, or with a regular interval of four hours. The following will show with what exactness these things may be made out:—

Nassick.	*Bombay.*
"6½ P.M.—Strong breeze from S.E. This soon became a perfect hurricane, and so continued a little more than half an hour, when it suddenly abated. It was accompanied by heavy rain and some hail; vivid flashes of lightning speedily followed, with crashing peels of thunder, till three o'clock A.M., when the breeze again freshened from S.E.	"9 P.M.—Gale of wind came on from N.E. Lasted about twenty minutes. At ten wind bore due north. Thunder, lightning and rain continued till two A.M. Wind had veered round from S.E. to S.S.E.

"The storm at Nassick was in reality in the sky seen at sunset from Bombay, though it did not reach us till four hours afterwards. The duration of this irregular state of things leads to the inference that atmospheric disturbances must have stretched far into the interior. The Nassick storm moved towards Bombay at the rate of twenty-four miles an hour."

Dr. Buist concludes by observing, "at present the irregularities of the weather at this usually regular and tranquil season of the year are so remarkable as to deserve every attention from the meteorologist." He then adds the letter giving an account of the storm at Nassick on the first eight days in April.

Subsequently to this storm, the Bombay papers of the 19th of June speak of an earthquake which extended over 10° of latitude and as many of longitude, having

been felt all along the line from Bombay to Simla; 35 inches of rain had also fallen in the first nineteen days of June, a quantity nearly equal to one-half of the average fall for the whole four and a half months of the monsoon.

Meteorologists need a philosophic and comprehensive explanation of the causes of such atmospheric disturbances, which not only have an important bearing upon vegetable development, but unquestionably have a most disastrous effect upon the public health. At one period during the last quarter in London the excess of deaths exceeded by 200 daily or 1400 per week the usual average, and this mortality, chiefly from influenza, exceeding that from the Asiatic cholera, was attributable to atmospheric causes.

I have thought it right to append the following rain-table as a valuable record.

Register of the Pluviometer at Bombay from 1817 to 1847.

Years.	June. Total fall in the month.	July. Total fall in the month.	August. Total fall in the month.	September. Total fall in the month.	October. Total fall in the month.	Total fall in June, July, Aug., Sept. and October in each year.
	inches.	inches.	inches.	inches.	inches.	inches.
1817	45·72	23·67	9·34	24·87	...	103·60
1818	22·54	17·69	28·45	10·39	2·00	81·14
1819	15·95	31·60	20·24	10·11	...	77·96
1820	18·82	28·37	19·49	10·66	...	77·34
1821	15·18	20·60	28·52	18·29	...	82·59
1822	29·64	26·59	33·83	22·16	...	112·22
1823	21·76	15·96	19·70	4·28	...	61·70
1824	3·89	8·07	17·86	1·78	2·27	33·97
1825	24·45	25·17	12·94	9·68	...	72·24
1826	17·75	26·97	8·40	23·50	1·87	78·49
1827	49·15	10·29	10·51	10·16	0·92	81·03
1828	23·53	52·75	17·22	22·08	6·40	121·98
1829	27·86	19·78	12·40	4·95	0·66	65·65
1830	20·96	32·46	10·66	7·78	...	71·86
1831	22·16	27·31	27·64	22·34	2·08	101·83
1832	13·63	48·05	4·65	7·11	0·65	74·09
1833	12·50	21·80	13·35	23·54	0·20	71·39
1834	14·16	21·83	18·05	12·55	3·88	70·47
1835	9·99	4·27	35·76	12·17	0·42	62·61
1836	21·36	24·05	37·41	4·69	...	87·99
1837	12·61	24·39	22·43	5·15	...	64·58
1838	29·70	8·70	7·34	5·04	...	50·78
1839	18·28	32·19	18·45	4·70	...	68·62
1840	25·04	24·24	4·20	7·55	2·12	63·15
1841	25·27	21·21	20·53	1·27	3·21	71·49
1842	16·84	26·45	37·10	10·41	4·36	95·16
1843	9·33	22·49	18·20	9·00	0·25	59·27
1844	14·17	35·52	6·55	9·16	...	65·40
1845	19·70	20·44	6·56	8·03	...	54·73
1846	31·71	40·56	5·60	8·45	1·16	87·48
1847	35·47	16·80	8·92	5·80	0·32	67·31
Average annual fall in the last 31 years						75·42

On the Compensation of Impressions moving over the Retina, as seen in Railway Travelling. By Sir DAVID BREWSTER, *K.H., D.C.L., F.R.S., & V.P.R.S. Edin.*

At the Meeting of the Association at Cambridge I communicated to this Section the general fact of the existence of a neutral line, or a line of compensation, when the retina is submitted, in succession, to impressions moving with different velocities and in the same direction. When we look, for example, at the lines into which the stones and gravel or other objects are drawn out by the velocity of the railway

carriage, and quickly transfer the eye to the same lines further back, the stones or gravel or other objects are, for an instant, distinctly seen, just as we see distinctly rapidly revolving objects in the dark when they are, for an instant, illuminated by an electric flash, or seen in daylight through rapidly revolving slits. I have observed the same phænomenon less perfectly when travelling in a mail-coach, when its velocity was ten or twelve miles an hour. It may be also seen and studied by means of the revolving disc of the phenakistoscope. If we suddenly transfer the eye from the marginal parts of the disc, where the velocity is greatest, to the parts nearer the centre of rotation, where the velocity is less, we shall, for an instant, perceive distinctly the figures drawn upon that part of the disc. I have not been able to find a satisfactory explanation of this phænomenon. It may be connected with the transverse motion which appears upon closing the eyes when under these moving impressions*, or from an opposite secondary motion accompanying the primary one, the velocity of the primary one being diminished during the transference of the eye to lines moving with the velocity to which the impression is then reduced.

The principal object of this notice is to describe a new fact which presented itself to me lately. If we look directly through a slit at the lines of moving stones, and suddenly look away from the slit, so as to see the moving lines through the slit by oblique or indirect vision, the stones will be distinctly seen.

This *neutral line*, or *line of compensation*, arises from a quite different cause from the former, and admits of a satisfactory explanation. When the eye is turned away from the slit, a part of the retina, not previously subjected to any impressions, must see the stones for an instant, but only for an instant, as their motion immediately obliterates the *first* distinct impression. The neutral line thus produced is not so easily observed as in the other experiment, where the stones are seen by the part of the retina on which vision is most distinct, the vision being in the one case oblique and in the other direct.

On the Vision of Distance as given by Colour. *By* Sir David Brewster, *K.H., D.C.L., F.R.S., & V.P.R.S. Edin.*

When the boundary lines on a map are marked with two lines of different colours, the one rises above or is depressed below the other, and the two lines appear to be placed at different distances from the eye. This remarkable effect is most clearly seen when we look with both eyes through a large reading-glass, spectacles being used along with it by those who require them. The more the two colours differ in refrangibility, the greater, and consequently the more distinctly seen, is the difference of distance at which the lines appear to be placed. The effect is finely seen in the coloured patterns of red and blue paper which Prof. Wheatstone has had executed on paper for exhibiting the mobility or shaking of one part of the pattern. The difference of distance of the coloured lines or spaces may be appreciated even with one eye.

The explanation of this phænomenon is very simple. In binocular vision the convergency of the optic axis to different points at different distances corresponding to the different points in the eye, to which the differently coloured rays are refracted, gives us the vision of a different distance for each coloured line, in the same manner as it is given in the stereoscope†. In monocular vision the distance is given by an analogous process to that by which the single eye sees distances.

On the Visual Impressions upon the Foramen Centrale *of the Retina.* *By* Sir David Brewster, *K.H., D.C.L., F.R.S., & V.P.R.S. Edin.*

The *foramen centrale* of the retina is an opening in that membrane varying from the 30th to the 50th of an inch in diameter. Although there is no nervous membrane over this opening, it is nevertheless the part of the eye which gives most distinct vision, and hence it has been supposed that the retina is not the sole agent in conveying visual impressions to the sensorium. Various attempts have been made to discover the existence of the *foramen centrale* by optical means, or to discover any effect produced by it on the incident light. In making some experiments on vision I was led

* See Report of 1845, Trans. of Sect. p. 8.
† See Edin. Transactions, vol. xv. p. 360.

to the solution of this difficulty, and at the last meeting of the Association at Oxford I mentioned the general fact, that when the eye had been for a short time closed and rested, and was then opened and directed to a moderately illuminated surface, a dark circular spot with a reddish brown penumbra, corresponding to the size of the foramen, was distinctly seen. The same effect was produced when the eye was not closed, but merely protected from light, which proved that the spot was not produced by the act of closing the eye, or by any pressure of the eyeball on its socket. By various measurements of the diameter of this spot I found it to subtend an angle of about 4 degrees 35 minutes; and by taking the radius of curvature of the retina at 0·5 of an inch, I found the diameter of the spot to be the $\frac{1}{25}$th of an inch, a result corresponding with sufficient accuracy with the measurement of the *foramen* in the dead eye, as given by Soemmering, who makes it about the $\frac{1}{20}$th of an inch. From this experiment it follows that when the eye is in its normal state, or in a state of rest, the *choroid coat* is less sensible to certain luminous impressions than the *retina* with the *choroid coat* behind it.

I now put the eye into an *abnormal* state, by exposing it for some time to a considerable degree of light, and upon repeating the preceding experiment, I saw upon the white ground a luminous spot, proving that when the eye was fatigued, or its sensibility diminished, the *choroid coat* was less affected than the *retina* and *choroid* acting together. Between these two extreme conditions of the eye, namely, when the eye was neither in a state of rest or fatigue, no spot whatever appeared, the *choroid coat* alone and the *retina* and *choroid coat* acting together, being equally sensible to light.

Anatomists have differed in opinion respecting the true form of the *foramen centrale*. Soemmering, the original discoverer of it, makes it *circular*. Some describe it as a *fold* in the *retina*, while others represent it as a *double opening* in the form of a *cross*. I have seen it myself in this latter form in the eye of a healthy person a few hours after death; but there can be no doubt that the process of removing the eye from its socket, and the pressure upon so tender a membrane as the retina by its separation from the membrane containing the *vitreous humour*, must alter the form of a *circular foramen*, shutting up the aperture and producing the appearance of a fold, or causing a double fold when it has the appearance of a cross. The roundness of the spot of variable sensibility I consider as establishing the true form of the *foramen centrale*, or of the *limbus luteus* which surrounds it.

An Examination of Bishop Berkeley's "New Theory of Vision." *By* Sir David Brewster, *K.H., D.C.L., F.R.S., & V.P.R.S. Edin.*

The object of this paper was to examine the theory of Dr. Berkeley—the foundation of the Ideal Philosophy—in its optical relations. The author demonstrated (in opposition to the fundamental assumption of Dr. Berkeley*), "that distance, both in monocular and binocular vision, is represented by lines on the retina." Hence every proposition of Dr. Berkeley's founded on that erroneous assumption falls to the ground. But even if the fundamental proposition on which he rests his theory had been true, it would have been true only *in vision with one eye*, and therefore could not be applicable to human beings, whose vision is performed by two eyes.

In support of his opinion that *we see outness and distance directly by the eyes*, and distinctly within a certain range of limited extent, while we judge of difference of distances beyond that range by various acquired means, the author described a number of experiments in binocular vision, where the eyes placed the object at a fixed distance, which the nicest sense of touch, and the most accurate knowledge of the true place of the object, could not in the least degree influence; and he supported his views by showing that the lower animals perceive distance at the instant of their birth, and that in every well-described case of the sudden restoration of sight in man by the extraction of the crystalline lens, or by the formation of an artificial pupil, *outness* and *distance* were invariably seen.

* "It is I think agreed by all, that *distance* of itself, and immediately cannot be seen; for distance being a line directed endwise to the eye, it projects only one point on the fund of the eye, which point remains invariably the same, whether the distance be longer or shorter."—*An Essay*, &c. § 1.

CHEMISTRY.

On the Action of the Red, Orange and Yellow Rays upon Iodized and Bromo-iodized Silver Plates after they have been affected by daylight, and other Phænomena of Photography. By A. Claudet.

It was shown by M. E. Becquerel, that the light which permeates red and yellow glasses had the property of continuing on a Daguerreotype plate the action of the light which causes the condensation of mercurial vapour on the surface. This property being in contradiction to that announced by Mr. Claudet when operating particularly with bromo-iodide of silver, he made some new experiments which completely confirmed the first, but showing at the same time the correctness of the fact discovered by M. E. Becquerel, as far as the action relates to a certain coating of iodine.

M. Gaudin, experimenting on the discovery of M. E. Becquerel, had found that red and yellow glasses not only continued the effect produced by light, but that an image might be developed under their influence without the action of mercury.

Investigations on these various subjects have enabled Mr. Claudet to discover that light alone also produces an image without mercury, quite similar to that obtained by M. Gaudin with the second action of red or yellow glasses. This curious fact, which had escaped Daguerre and all his followers, affords to Mr. Claudet a means of offering an explanation of the phænomena elucidated by M. E. Becquerel, and proposing a new theory of the formation of the Daguerreotype image.

Mr. Claudet thinks that the image produced by light alone is due to the decomposition of the iodide of silver, by which silver is precipitated on the surface in a finely divided powder or crystals, producing an effect similar to that caused by the condensation of mercurial vapour.

The red or yellow rays having a photographic action of their own, very slow on the non-affected parts, but capable of operating more strongly on the parts already affected by white light, continue that precipitation of finely divided silver, and when the action of the red or yellow rays is added to the condensation of mercurial vapour, it doubles the effect by which the image appears visible. This would explain the action called *continuation* by M. E. Becquerel, as well as the phænomenon of the image developed by the red or yellow glasses according to M. Gaudin's discovery; the only difference being that M. Gaudin continues the action of the red or yellow rays until they have fully and visibly determined the precipitation of the silver.

Mr. Claudet concluded by stating, that he had been able to ascertain that the pure light of the sun can produce on the surface of bromo-iodide of silver the change of modification by which it acquires the affinity for mercurial vapour in the incredible short space of time of about $\frac{1}{1000}$th part of a second.

On the Laws of Chemical Combinations and the Volumes of Gaseous Bodies. By the Rev. Thomas Exley, *M.A.*

Were we acquainted with the laws of force at minute distances, as we are with gravitation, the grand difficulty respecting chemical combinations would be overcome; but while these laws remain unknown the subject will remain in its present state, involved in a labyrinth. It has been of late too much the fashion to discard hypotheses. Newton discovered the law of gravitation; but how? by first admitting it hypothetically, and then testing the hypothesis by calculation. Newton failed to assign the laws of force at very small distances; he carried the law of gravitation to a limit near the centre of an atom, and concluded from phænomena which he observed, that there follow several spheres of force alternately attracting and repelling. So long as the laws of these forces remain unknown, no true theory can be established. It is therefore best to assign some hypothesis which fixes some probable law of force, and then to calculate the effects; the author assumes nothing more than that the force of gravitation is continued to the centre of atoms, and that it acts outwardly in a small central sphere, constituting a small sphere of repulsion:

this is the peculiar feature in his new theory of physics; and all the varieties of atoms arise from differences in their absolute forces and the extent of their spheres of repulsion. Deductions from this theory agree with experiment and observation.

From this theory he has deduced the alternate spheres of force observed by Newton with electrical attraction and repulsion, not as peculiar forces, but as circumstances dependent on the combinations of the classes of atoms mentioned below, and the following laws of chemical combination, viz.—Law I. That two atoms, simple or compound, combine one with one without the intervention of a third, and that the volume remains unaltered, or is contracted one half. Law II. Two atoms combine by the intervention of a third, and the volume remains the same as that of the two combined atoms, or is reduced exactly one half. These laws he has examined in about one hundred cases, in which he finds them confirmed by experiment without exception.

In order to explain these laws, he takes what is presented by many phænomena, that there are three classes of atoms.—Class I. Such as have comparatively a small sphere of repulsion and a great absolute force; such are the common elements of chemists; hydrogen, nitrogen, carbon, &c. Class II. Such as have a large sphere of repulsion and a small absolute force; these he is persuaded constitute the electric fluid. Class III. Such as have a very large sphere of repulsion and a very small absolute force, which, when in motion, as it seems to him, constitute caloric, light and actinic rays, one or other, according to their velocity.

Now if into a vessel containing atoms of the second and third classes under compression there be introduced a considerable number of those of the first class, each of these will become a supporting centre against the reaction of the other classes: it is evident that these centres will be uniformly disposed, and that their distances will be equal to the distances between the atoms of the interior surface of the vessel and the adjacent atoms of the gas, and the pressure between the atoms will increase with the number of these, considered as supporting centres; hence under a given pressure the volume will depend on the number of supporting centres. Thus if the same number of atoms of nitrogen be substituted for the hydrogen, the volume will not be altered, although the nitrogen is fourteen times heavier than hydrogen; it will be still the same if we have the same volume of chlorine, which is thirty-six times heavier than hydrogen. The same observations apply to iodine, bromine, &c. and to oxygen, taking its atomic weight at sixteen; thus we find that the volume depends not on the absolute force and sphere of repulsion of the atoms, but on the number of supporting centres.

The same holds good in compound atoms; thus, muriatic acid is H.·.Cl, nitric oxide O.·.N, carbonic oxide O.·.C, which are instances of the first law where the volume remains unaltered, and this doubtless takes place when the electric matter collects between the combining atoms; thus light acting on a mixture of hydrogen and chlorine causes the electric fluid to collect between them; hence the number of supporting centres remains the same, and the distance between the atoms of hydrogen and chlorine is unaltered; which holds good in the other examples, and all similarly combined. Examples where the volume is contracted one half are, cyanogen N C, E. Davy's carburet of hydrogen H C, &c.; here the electric fluid collects on the exterior sides.

As illustrations of the second law take water vapour H(O)H, carbonic acid O(C)O, alcohol $H_2C(H_2O)CH_2$, æther vapour $H_4C_2(H_2O)C_2H_4$, œnanthic æther $H_4C_2(H_{26}C_{14}O_2, H_2O)C_2H_4$, ethal $H_{16}C_8(H_2O)C_8H_{16}$, &c., in which and all such the volume is the same as that of the extremes, where the connecting atom makes no part of the volume, being protected and prevented from becoming a supporting centre by the intervening electric fluid, which produces the combination; thus, for instance, in œnanthic æther, the forty-five atoms of œnanthic acid do not alter the distance of the etherine H_4C_2, H_4C_2, and the same in all such cases, where the volume is the same. As examples, where the volume is reduced exactly one-half, we have olefiant gas HCH, nitrous acid ONO, benzin or Dr. Faraday's carburet of hydrogen HC, HC, HC, where the extremes connected by the intermediate atom are reduced to one centre of support, the electric fluid collecting on the exterior sides; sulphur vapour is analogous to benzin, being S, S, S reduced to one centre of support. In all cases where the specific gravity of the gas is found, these laws of com-

bination and volume are found to hold universally. On these principles Mr. Exley calculates the specific gravity of gaseous bodies by multiplying the atomic weight, on the hydrogen scale, by 10, and dividing by 144, when the volume is contracted one half; and again, by 2, when the volume is unaltered; thus, for æther the atomic weight is 74, then $740 \div 12 \times 12 \times 2 = 2{\cdot}5694$. Gay-Lussac finds it 2·586 by experiment. Thus are these laws established.

Since it is shown by the theory, and proved by experiment, that equal gaseous volumes of hydrogen H, nitrogen N, nitrous acid O_2N, olefiant gas H_2C, etherine H_4C_2, cetine $H_{16}C_8$, &c., contain an equal number of atoms, the centres or centres of gravity of the atoms, simple or compound, are equidistant, and that distance is not altered when every two are united by intervenient electric atoms, or by such atoms and any number of elementary atoms whatever, if they are screened by the electric atoms, so as not to become centres of support.

On the Motion of the Electric Fluid along Conductors. By the Rev. THOMAS EXLEY, *M.A.*

Professor Wheatstone made some valuable experiments, showing that in traversing a long conductor the electric spark occurs at the same time at each end of the circuit, and latest at some part near the middle; this has been considered as a proof that there are two electric fluids; but this conclusion is too hasty, for it may be shown that the phænomena ought to be such on the supposition of a single fluid.

When an electrical charged plate is discharged, there are only three ways, worthy of notice, by which the equilibrium can be restored:—

1. The passage of the fluid through the circuit, commencing either at the positive or negative end.
2. Its passage in pulses beginning at one or the other end.
3. Its passage in pulses taking their rise simultaneously at both ends and closing about the middle.

In order to obtain correct views we must attend to the phænomena of charging an electric plate.

If the knob of the prime conductor, electrified to a certain intensity, were presented to the bare surface of a thin plate of glass, the particles of the glass would receive and retain a small quantity of the electric fluid without suffering it to pass on far, or they would give a small quantity without receiving a fresh supply from distant particles; a higher intensity or a nearer approach of the prime conductor would give or take another spark, and the neighbouring particles of the glass would receive or give fluid to a small distance farther, where the progress would be arrested.

But when the plate is furnished with the usual coating, the spark of electric fluid affects in like manner all the superficial particles of the glass to the limits of the coating. If now an uninsulated conductor be presented to the opposite side, a spark will pass between it and the coating, and at the same time another spark between the prime conductor and the coating, and a succession of simultaneous sparks on the opposite sides will occur so long as the same intensity of the conductor is maintained, until the plate is charged.

These phænomena assure us, that although the fluid penetrates only to a very small depth in the glass plate, yet the addition or abstraction of the fluid affects the particles of the plate, as far as the opposite side, producing in them a tendency to give fluid to, or to receive fluid from, the uninsulated conductor on the other side. Thus the particles of the glass have obtained a tendency to receive fluid on the sides towards the positive conductor and to give it from their opposite sides. Thus will all the particles of the glass which are situated directly between the opposite conductors be affected; but at a distance from that line of particles, both sides of the plate will be in the same condition as the prime conductor by which the charge is made. When the charged plate is removed, the receiving sides of the particles will be towards the negative surface of the plate, and the delivering sides towards the positive surface. The discharging rod being now applied with its knobs at such a distance as not to receive a spark, the same condition of the particles will remain in the plate, and will be propagated in the same direction on the particles of air contiguous to the rod through the whole circuit; the particles of air contiguous to the

rod will be in a condition to receive on the sides facing the positive coating, and of giving on the sides facing the negative coating; that the rod is neutral in the middle arises from the opposite and equal tendencies of the extremes. Now let the knobs approach to make the discharge. This is not effected by a continuous passage of the fluid from one end to the other, since, at any break in the circuit, a card, being interposed, is pierced so as to have a bur on both sides, showing that the passage was made in pulses; nor do these commence at either end and proceed to the other, for the one end cannot wait to receive or to give during the time of the passage. The pulses must therefore commence simultaneously at both ends, and close about the middle, where, consequently, the spark would be last seen. Besides there is no reason whatever that the motion should begin at one end rather than the other; and the same follows from this, that the one side of the discharging rod is positive, and the other equally negative, while it is neutral in the middle.

Therefore, on the supposition of only one electric fluid, the spark ought to be seen precisely at the same time at the two extremities, and latest of all about the middle of the rod: also the explanation by one fluid presents fewer difficulties than by two fluids. The observations made were applied to the explanation of some other electrical phænomena, as the residual charge, the charging of thin and thick glass, the star and brush, &c.

On the Identity of the Existences or Forces of Light, Heat, Electricity, Magnetism and Gravitation. By John Goodman.

The author has already shown in a former communication that the substance potassium, which displays the highest chemical properties, possesses also the most exalted electrical powers. In order to show the further prominence of this metal in its calorific phænomena, he devised several experiments, and has succeeded in showing that potassium contains also the greatest known amount of caloric of any solid material body.

When this metal was subjected to percussion or screw compression in a steel cylinder by means of an air-tight piston, also of steel, *a flame of considerable dimensions* was discovered to issue from a minute orifice—being given off from the interstices of the metal as water from a sponge—and this frequently accompanied by a *loud explosion*. By enlarging the orifice the flame and explosion would gradually diminish, until large portions only of red-hot metal would exude during percussion.

The explosion was found by experiment to be caused by the combustion of the finely-divided particles of heated metal which escaped, depriving the atmosphere of its oxygen and producing an instantaneous collapse of the surrounding air, as is represented to be the case immediately after the transition of lightning.

The author attributes the escape of caloric through so small an orifice, and by the sides of the piston, instead of by radiation to the adjoining excellently conducting cylinder, to the *intense attraction* of caloric for potassium.

The pure flame seen in these experiments was projected *in vacuo* as in oxygen, but with considerably diminished splendour, showing that it exists independently of combustion.

The author ascribes to caloric attraction for other kinds of matter, and supposing that all bodies are naturally either *minus* or *plus* as regards their amount of caloric, and attract each other simply as in electrical phænomena, proposes to explain thus the force of gravitation and the attraction of cohesion.

He points out the great precision with which the numbers given by philosophers to represent capacity correspond with the powers of electric affinity of the various metals, as exhibited in thermo- and mechanical electricity, and suggests that electrical affinity and "capacity" are not improbably analogical.

"Potassium is thus found (says the author) to possess a vast amount of caloric and to exhibit calorific phænomena, of which no other solid substance in nature is known to be capable, and it is therefore not improbable that its extraordinary chemical and electrical powers are derived from the *quantity* of latent heat which it contains."

Employing the argument used in his former communication that chemical and electrical phænomena are one and the same thing, because the substance producing

the highest chemical, developes also the most exalted electrical, phænomena, the author infers that chemical and electrical forces and caloric are one and the same thing, because the substance developing the highest chemical and electrical powers displays also the greatest capacity for, and contains the most intense quantity of heat. Thus chemical and electrical forces appear to be only modifications or manifestations of calorific agency.

The author shows that M. Melloni employs the same arguments for the proof of the analogy of light and heat. He adduces certain experiments of Professor Draper to show that a strip of platinum *heated by the voltaic current* corresponds with minute precision in the development of light and heat at all times; but that author has overlooked the equally manifested analogy of these two forces with the force from which they are developed—the fountain whence they are derived—employed in these experiments.

On the peculiar Cooling Effects of Hydrogen and its Compounds in cases of Voltaic Ignition. By W. R. GROVE, *F.R.S.*

This communication was illustrated by an experiment, in which it was shown that a platina wire, rendered incandescent by a voltaic current, was cooled far below the point of incandescence when immersed in an atmosphere of hydrogen gas. This remarkable cooling property of hydrogen of course became the subject of experimental examination in comparison with other gaseous media. By a peculiar arrangement, tubes containing coils of platina wire were filled with hydrogen and other gases, and then being plunged into water in which delicate thermometers were placed, the wires were traversed by the same current from the battery, and it was found that the water was always more heated in a given time by the wire in the tubes of oxygen, nitrogen, or carbonic acid, than in those of carburetted hydrogen, olefiant gas or pure hydrogen. It became necessary now to ascertain the cause of this peculiar phænomenon of hydrogen. It was found not to be due to specific heat, to specific gravity, nor to any conducting power of the gases; and some difficulty was found upon examination to exist if it was attempted to refer it to the greater mobility of the particles of hydrogen gas as the lightest known, than of oxygen, nitrogen, carbonic acid, &c. It was found that this peculiar property also belonged, but to a less extent, to all the hydrocarbonous gases. The author considered it might be due to a readiness of convection of heat from the ignited surface, hydrogen being, as compared with the other gases, in the same relation to the heated body as a black surface is when compared with a white one.

On the Colouring Matters of Madder. By JAMES HIGGIN.

The author, after describing the three colouring matters of madder, xanthin, rubiacin and alizarin, and the means he employs to separate them in a pure form, proceeds to show that the opinion usually entertained—that it is the alizarin only which is the valuable part of madder—is incorrect; and experiments are adduced to prove that in proper circumstances, such as obtain in ordinary madder-dyeing, the xanthin and rubiacin contribute very materially to the effect. They are shown not to act directly, but through becoming changed into alizarin, which then combines with the mordants. This change is considered by the author to be induced by a peculiar azotized ferment, found in madder, whereby xanthin becomes rubiacin and this latter alizarin; and the opinion is held out that all colouring matter in madder is derived primarily from xanthin.

On the Influence of Light in preventing Chemical Action. By ROBERT HUNT.

Having called attention to several experiments in which certain luminous rays had been found to protect photographic agents from chemical change, particularly in the researches of Sir John Herschel, the author proceeded to describe his own experimental investigation of this subject.

Taking a piece of highly sensitive photographic paper, which would blacken in a few seconds by the light of an Argand gas-burner, he threw upon it a condensed spectrum which had been previously analysed by a peculiar yellow medium, and then by means of a mirror reflected the strong light of the sun upon the paper. It was, therefore, under the influence of the reflected radiations without any change, and also of the spectrum from which the chemical agency had been as nearly as possible separated. The result was, that the paper was blackened over every part, except that portion upon which the strong line of spectral light fell, which was protected from change *and preserved as a white band* in the midst of the darkened paper. This experiment was thought by the author strongly confirmatory of the view which he had taken, that actinism, or the chemical principle, and light, so far from being identical, were opposed in action to each other.

Analysis of Wrought Iron produced by Cementation from Cast Iron. By Prof. W. A. Miller, *M.D., F.R.S.*

The following are the results of an examination of the chemical composition of a specimen of brittle cast iron, which was by a subsequent process converted into malleable iron by cementation.

The ore from which this iron was obtained is the Lancashire brown hæmatite from the neighbourhood of Ulverstone; it is smelted with charcoal instead of with coke: the articles to be rendered malleable are first of all cast in the desired form. They are in this state formed of a nearly white, very hard, brittle iron, which exhibits a crystalline grain on fracture. To convert these extremely brittle articles into malleable iron fit for the forge, they are imbedded in powdered hæmatite and maintained at a red heat for some hours; the carbon is thus gradually removed by inverting the usual operation of converting bar-iron into steel, and the result is the production of a tough iron, which may be hammered either hot or cold.

A careful qualitative analysis showed that besides iron, carbon and silicon, traces of aluminum, sulphur and phosphorus were present, while no arsenic, antimony or manganese were there; titanium was not detected.

The author stated in detail his process for the analysis, and added the following observations:—

It is to be noticed that considerable change in the specific gravity occurred in the iron after cementation; it was forged, and was then found to have increased in density: the brittle iron had a specific gravity of 7·684; the malleable, 7·718.

The results of analysis are briefly these; the quantity both of carbon and silicon are materially diminished by the cementation, though still the proportion of both is greater than in good bar-iron. It also appears that the portion of carbon which is insoluble in acids is nearly the same both before and after the iron has been rendered malleable, the diminution being confined almost to that portion of carbon which was chemically combined with the metal, and which therefore would be in a state for propagation through the mass more readily by cementation.

	Cast Iron.	
	Brittle.	Malleable.
Specific gravity	7·684	7·718
Iron		
Carbon	2·80	0·88
Silicon	0·951	0·409
Aluminum	trace	trace
Manganese	none	none
Titanium	0	0
Arsenic	none	none
Sulphur	0·015	
Phosphorus	trace	trace
Sand	0·502	
Carbon combined	2·217	0·434
Ditto uncombined	0·583	0·446

Prof. Miller also had occasion to examine a specimen of iron known as cold-short from the Staffordshire district. In texture it appeared to be entirely destitute of the fibrous character, but to consist of a series of small laminæ or plates. In addition to carbon and silicon, he found phosphorus, an appreciable quantity of copper and decided traces of potassium. The copper he has no doubt is derived from the coal employed in the smelting, from an examination of several species of coal lately made in the laboratory of King's College by Mr. Vaux. Copper is found in many, none being met with in the Newcastle coal, but a quantity distinctly appreciable in the ashes of the Staffordshire coal. The potassium, it is just conceivable, might have been derived from the glass vessels in which the operation was conducted, but the author has little doubt it was furnished from the iron itself: upon this point however further experiments are needed to remove all ambiguity.

Red-short iron is frequently supposed to owe its defective qualities to the presence of sulphur. In a specimen, however, which he examined with great care, Prof. Miller could not find any notable proportion of sulphur, and indeed though minutely examined for tin, arsenic, antimony, titanium, manganese, chromium, aluminum and calcium, he could not find, with the exception of a trace of the latter, any substance beyond the ordinary constituents of wrought iron, viz. iron with a small quantity of carbon and silicon. A trace of phosphorus was however distinctly ascertained (it did not exceed 0·0114 per cent.), and the sulphur was not more than 0·016.

He believes, however, that traces of potassium exist in this iron also.

	Staffordshire Iron.	
	Hot-Short.	Cold-Short.
Specific gravity	7·426	7·921
Iron		
Carbon	0·245	0·275
Silicon	0·232	0·288
Aluminum	none	none
Manganese	none	none
Titanium	none	none
Arsenic	none	none
Chromium	none	none
Copper	0	0·041
Sulphur	0·016	trace
Phosphorus	0·011	0·337
Calcium	trace	none
Potassium	traces	trace

On the existence of Ozone in the Atmosphere. By Dr. MOFFATT.

On a peculiar property of Coke. By JAMES NASMYTH.

The following fact, which was observed by the author some years ago, appears to furnish additional evidence as to the identity of the diamond with carbon. Mr. Nasmyth states that *coke* is possessed of one of the most remarkable properties of the diamond, in so far as it has the property of *cutting glass*. He uses the term *cutting* expressly in contra-distinction to the property of scratching, which is possessed by all bodies that are harder than glass. The *cut* produced by coke is a perfect clear diamond-like cut, so as to exhibit the most beautiful prismatic colours, owing to the perfection of the incision.

Coke hitherto has been considered as a soft substance, doubtless from the ease with which a mass of it can be crushed and pulverized; but it will be found that the minute plate-formed crystals, of which a mass of coke is formed, are *intensely hard*, and, as before said, are possessed of the remarkable property of *cutting* glass.

This discovery of the extreme "diamond-like" hardness of the particles of coke will no doubt prove of value in many processes in the arts as well as interesting in a purely scientific sense.

On the Chemical Character of Steel. By James Nasmyth.

Were we to assume as our standard of the importance of any investigation the relation which the subject of it bears to the progress of civilization, there is no one which would reach higher than that which refers to the subject of steel; seeing that it is to our possession of the art of producing that inestimable material that we owe nearly the whole of the arts. Mr. Nasmyth is desirous of contributing a few ideas on the subject, with a view to our arriving at more distinct knowledge as to what (in a chemical sense) steel is, and so of laying the true basis for improvement in the process of its manufacture.

It is well known that steel is formed by surrounding bars of wrought iron with charcoal placed in fire-brick troughs from which air is excluded, and keeping the iron bars and charcoal in contact and at a full red heat for several days; at the end of which time the iron bars are found to be converted into steel. What is the nature of the change which the iron has undergone we have no certain knowledge; the ordinary explanation is, that the iron has absorbed and combined with a portion of the charcoal or carbon, and has in consequence been converted into a carburet of iron: but it has ever been a mystery, that on analysis so very minute and questionable a portion of carbon is exhibited. It appears that the grand error in the above view of the subject consists in our not duly understanding the nature of the change which carbon undergoes in its combination with iron in the formation of steel. Those who are familiar with the process of conversion of iron into steel, must have observed the remarkable change in the outward aspect of the bars of iron after their conversion, namely, that they are covered with blisters. These blisters indicate the evolution of a very elastic gas which is set free from the carbon in the act of its combination with the iron. Mr. Nasmyth is led to think that these blisters are the result of the decomposition of the carbon, whose metallic base enters into union with the iron and forms with it *an alloy*, while the other component element of the carbon is given forth, and so produces in its escape the blisters in question. On this assumption, that steel is *an alloy* of iron with the metallic base of carbon, it would be a most interesting subject of investigation to endeavour to ascertain what is the nature of the evolved gas which produces these blisters. In order to do this, the author proposes the following process:—Fill a wrought iron retort with a mixture of pure carbon and iron filings, subject it to a long-continued red heat, and receive the evolved gas over mercury. Having obtained the gas in question in this manner, then permit a piece of polished steel to come in contact with this gas, and in all probability we shall then have *reproduced*, on the surface of the steel, a coat of carbon resulting from the reunion of its two elements, namely, that of the metallic base of the carbon then existing in the steel with the (as yet) unknown gas, thus synthetically, as well as by analytic process, eliminating the true nature of steel and that of the elements or components of carbon.

On some of the Alloys of Tungsten. By John Percy, *M.D., F.R.S.*

Dr. Percy detailed a series of experiments upon the economic use of tungsten in alloys. The tungsten employed was obtained in the form of steel-gray powder from tungstate of ammonia in the usual way. It was heated at a very high temperature with gold, silver, copper, nickel, and the alloy of metal, copper and zinc, called German silver, respectively, charcoal powder being added to prevent oxidation. *Apparent* alloys were thus obtained; but on testing them by the ordinary manufacturing processes of rolling, scratching and polishing, it became evident that the tungsten was simply diffused through the mass in minute grains. A mixture, for it cannot be called an alloy proper, of copper and tungsten was produced containing 22 per cent. of tungsten; the colour of the copper was not thereby very minutely altered, so that tungsten does not possess the whitening property of nickel. The results of these experiments were quite unsatisfactory in regard to the economic application of tungsten. The subject still deserves the attention of metallurgists.

On some Properties of Alumina. By R. PHILLIPS, *F.R.S.*

It has been observed by Wittstein, that the precipitate which is obtained from the persulphate or perchloride of iron, if kept for a great length of time in water, loses almost entirely the property of being soluble in acetic acid. Mr. Phillips had noticed a similar phænomenon with alumina, arising without doubt from the action of the cohesive forces. Whereas the sesquioxide of iron requires one or probably two years for the production of the effect, alumina undergoes the change partially in a very short time; the precipitated alumina does not, however, assume a crystalline appearance—stated to be the case with the cohering sesquioxide of iron. If the precipitated alumina is kept for two days moist and in the solution from which it was precipitated, even sulphuric acid does not immediately dissolve it. Experiments were brought forward in proof of this fact. It was also shown that the interposition of magnesia or of carbonic acid prevented the alumina from cohering.

On Common Salt as a Poison to Plants. By W. B. RANDALL.

In the month of September last, three or four small plants in pots were shown to the writer, nearly or quite dead; and he was at the same time informed that their destruction was a complete mystery to the party to whom they belonged, and that Dr. Lindley had expressed his opinion, from the examination of a portion of one sent to him, that they were poisoned. Having searched in vain for any strong poison in the soil, and in the plants themselves, he inquired more minutely into the circumstances of the case, and found that these were only specimens of many hundreds of plants both in the open air and in green-houses (but all in pots) which exhibited, in a greater or less degree, the same characteristics. The roots were completely rotten, so as to be easily crumbled between the fingers; the stems, even in young plants, assumed the appearance of old wood; the leaves became brown, first at the point, then round the edge, and afterwards all over, while the whole plant drooped and died. At least 2000 cuttings in various stages of progress, and 1000 strong healthy plants had been reduced to this condition, including different varieties of the fir, cedar, geranium, fuchsia, rose, jasmin and heath. The sight of this wholesale destruction, coupled with the fact that all the plants were daily watered from one particular source, suggested the conclusion that the cause of the evil might be found in the water thus used; and this was accordingly examined. It yielded the following constituents, making in each imperial pint of 20 fluid ounces, nearly 9½ grains of solid matter, entirely saline, without any organic admixture:—

Carbonate of lime	0·600
Sulphate of lime	0·462
Chloride of calcium	0·200
Chloride of magnesium	1·252
Chloride of sodium	6·906
	9·420

The mould around the plants, and an infusion of the dead stems and leaves also afforded abundant evidence of the presence of much chloride of sodium. Further inquiry showed that the well from which the water was procured had an accidental communication, by means of a drain, with the sea, and had thus become mixed with the salt water from that source, and had been used in this state for some weeks, probably from two to three months. From about that time the plants had been observed to droop, but it was not until nearly the whole of a valuable stock had been destroyed that any extraordinary cause of the evil was suspected. To place it beyond doubt that the water was really the cause of the mischief, twelve healthy fuchsias were procured from a distance and divided into two parts, half being watered morning and evening with the water in question, and the others with rain-water. In a week the six plants watered from the well had turned brown and ultimately died, while all the rest remained perfectly flourishing. Assuming from these facts that the common salt in this water was the chief cause of the results described, it is proved that water containing about seven grains of salt in each pint is, in its continued use, an

effectual poison to the weaker forms of vegetation, or that when a soil is continually watered with a weak solution of salt it gradually accumulates in it until the soil becomes sufficiently contaminated to be unfit to support vegetable life. In either case an interesting subject of inquiry is suggested—What is the weakest solution of salt which can produce this poisonous effect? or in other words, at what degree of dilution does the danger cease? For salt is an important natural constituent of much spring-water, quite independent of any infiltration from the sea, as in this instance.

Thus, the water of the Artesian well, Trafalgar Square, London, contains in each gallon about	20·0 grains.
That at Combe and Delafield's brewery	12·7 ,,
That at Woolverton Railway Station	6·0 ,,
One lately sunk at Southampton for supplying a private manufactory	40·0 ,,

May it not be asked whether the subject of the suitableness of waters in general for the various purposes to which they are applied,—be it in manufactures or for steam-engines, domestic purposes or drinking,—is not worthy of a greater share of scientific attention than it has hitherto commanded?

On a New Process for analysing Graphite, Natural and Artificial. By Professor R. E. Rogers, *and Professor* W. B. Rogers, *University of Virginia.*

The present abstract will be limited to a brief statement of the principal steps of the new process, and such reference to the results as is necessary to give assurance of its accuracy. The details of the operation, with a description and drawing of the apparatus employed, will appear in the forthcoming number of the American Journal of Science.

The extreme obstinacy with which graphite, natural as well as artificial, resists oxidation by liquid re-agents is shown by the fact that neither nitric nor sulphuric acid, used singly, even with the aid of heat, produces any sensible effect upon the flakes of this substance. Schafhaeutl succeeded in oxidating scales of artificial graphite by surrounding them with boiling sulphuric acid and then dropping concentrated nitric acid upon the liquid, but the action was so slow as to require several successive digestions of the same specimen to dissipate the whole of the carbon.

The new process is founded on the fact that a mixture of bichromate of potassa and sulphuric acid, when applied in great excess to very minutely-divided graphite, converts the carbon rapidly and completely into carbonic acid. The fact of such a reaction was noticed by us more than two years ago, but the details of the present process were not matured until the winter of 1847, since which time we have used it in a number of instances for determining the carbon of graphite, and always with consistent and satisfactory results.

Our method of proceeding is briefly as follows:—

1. *Apparatus used.*—The object of the experiment being to convert the carbon of the graphite into carbonic acid, and by absorption to collect the whole of the latter, with the view of deducing from it the weight of the carbon, the apparatus is constructed of the following parts:—*First*, a retort for receiving the powdered graphite, bichromate of potassa, and sulphuric acid; *second*, a large drying tube of chloride of calcium to arrest moisture; *third*, a Liebig tube charged with standard solution of potassa followed by a small U-tube of fragments of potassa, both designed for the detention of the carbonic acid evolved; *fourth*, an additional U-tube to arrest the moisture which might otherwise pass backwards from the aspirator; and, *fifth*, a large aspirating apparatus, to be used at the close of the experiment. The neck of the retort is bent upwards at right angles and enclosed in moistened cloth or by a glass refrigerator, to prevent the passage of sulphuric acid vapour into the chloride of calcium.

2. *Preparation of the Graphite.*—To ensure a prompt and complete result, the graphite must first be brought to the *most minute division*. This cannot be effected by triturating it alone, but is readily done by grinding it with pure quartz sand, or what is better, with small fragments of granular quartz, adding this substance in successive portions during the grinding, until it amounts to some thirty times the weight

of the graphite used. The success of the oxidating process is greatly dependent on this preparation. Ground in the ordinary way, we have found 6 grains of pure graphite to require upwards of twelve hours for complete oxidation, while the same amount finely ground with silica was completely dissipated in about thirty minutes.

3. *Mixture.*—With a retort of about 15 cubic inches we find 6 grains of graphite a convenient quantity to operate with. When prepared as above, it is to be mixed with 500 grains of powdered bichromate of potassa, and the whole being transferred to the retort, we add 1 cubic inch of water, and then pour slowly upon the mass 5 cubic inches of sulphuric acid of the common density, taking care to mingle the ingredients by gentle agitation as we add the acid. A moderate lamp-heat soon excites brisk reaction, which is afterwards to be regulated by withdrawing or renewing the heat. At the close, the small tube attached to the tubulure of the retort is opened to permit aspiration, and a volume of air, equal to two or three times the capacity of the retort, is drawn through the apparatus.

Results.—The consistency of the results obtained by this method will be seen from the following examples, selected as fair specimens of a number of experiments performed in the same way:—

Native Graphite.—A crystalline variety found in Albemarle county, Virginia. It occurs in long flat narrow plates of a curved form, packed closely together like the fibres of asbestus.

6 grains of this mineral yielded—

In the first experiment .... Carbonic acid, 20·79
„ second „ .... Carbonic acid, 20·82

The mean corresponds in 100 grains to Carbon 94·56.

Artificial Graphite or Kish.—In large crystalline plates with adhering iron and slag. The former was removed by digestion in acid, but some of the vitreous matter remained.

6 grains of this substance yielded—

In the first experiment .... Carbonic acid, 16·58
„ second „ .... Carbonic acid, 16·63

The mean corresponds in 100 grains to Carbon 75·4 grains.

To test the *accuracy* of the results, weighed specimens of graphite were carefully burnt to ash in a current of oxygen gas. The weight of carbon found by subtraction closely corresponded with that determined by the liquid process applied to the same specimen.

It is proper to add, that the native graphite used in these experiments was first freed from any adhering carbonates or organic matter, by digestion in dilute sulphuric acid and subsequent ignition.

We have made numerous experiments to test the applicability of this process for determining the *carbon of coals*. In the *driest* varieties of anthracite, the results presented a good degree of uniformity in repeated trials with the same specimen; but wherever the coal contains a volatile compound of carbon, this is in greater or less part evolved without oxidation in virtue of the high temperature of the reaction. In the case of perfectly dry coke however the process gives uniform and accurate results.

Oxidation of the Diamond in the Liquid Way.
By Professors R. E. Rogers *and* W. B. Rogers.

The processes for oxidating the diamond hitherto described, consist in *actually burning* this gem, either in the air, in oxygen gas, or in some substance rich in oxygen, as nitrate of potassa. In all these experiments a very elevated temperature is required. We have therefore been much interested by discovering that the diamond may be converted into carbonic acid in *the liquid way and at a moderate heat*, by the reaction of a *mixture of bichromate of potassa and sulphuric acid*; in other words, by the oxidating power of chromic acid. This fact, although suggested in the progress of our experiments on graphite, was not unequivocally ascertained until lately.

The method of proceeding is much the same as in the oxidation of graphite, but the progress of the oxidation is a *great deal slower*.

To succeed in this experiment, it is necessary first to reduce the small chips of diamond used in the process to a very fine powder. This is done by crushing them in a steel mortar, and then grinding the coarse powder that results with repeated portions of pure siliceous sand in a mortar of agate. By patient manipulation we have in this way succeeded in bringing the diamond to *very minute division*.

A single grain weight of the gem will suffice for several experiments. In our repeated trials we have never used more than half a grain, and we have obtained clear evidence of oxidation, by the evolved carbonic acid, with even one-tenth of a grain.

In operating with half a grain, we employ a retort of about 15 inches capacity fitted up as in our apparatus for the oxidation of graphite. The Liebig tubes and U-tubes of that arrangement are replaced by tubes or small bottles charged with perfectly clear *lime-water*, and connected by bent tubes and perforated corks, so as to be air-tight at all the junctures. The drying tube of chloride of calcium is omitted, and in its place a slender tube connected with the beak of the retort carries the gas through a short test-tube containing a small quantity of water. This is adopted as a precaution in the event of sulphuric acid vapour escaping uncondensed.

As the process is slow we find it necessary to use a large amount of the oxidating materials. In our experiments with half a grain the retort is charged with 4 cubic inches of sulphuric acid and 500 grains of bichromate of potassa.

It is important to remark that these materials, *of themselves*, when heated to the temperature at which oxygen is evolved, never fail to yield a small amount of carbonic acid. This result, due no doubt to the presence, in the bichromate, of a trace of carbonate or some carbonaceous matter, we have found it impossible entirely to prevent by re-crystallization or the addition of acid to the salt, or even by continued ignition. But we avoid all chance of error from this cause, by first heating the acid alone in the retort to about 350°, then adding the bichromate by degrees, and stirring the mixture so as to effect a complete separation of the chromic acid. A very brisk reaction takes place, much oxygen is disengaged, and with it any carbonic acid which these materials themselves are capable of evolving.

By using successive tubes of lime-water to test the evolved gas, and occasionally applying a lamp to the retort, we readily ascertained when the oxygen ceases to be mingled with carbonic acid; and as soon as we are assured of this we add the powdered diamond, and begin the main experiment.

The evolution of carbonic acid is soon evinced by the growing milkiness of the lime-water, and this continues slowly to augment as long as there is free chromic acid in the retort.

Operating in this way with half a grain of diamond-powder and the proportions of sulphuric acid and bichromate above stated, we have in a first process obtained about six-tenths of a grain of carbonate of line, about *one-seventh* of that due to the weight of diamond considered as pure carbon, showing that about *one-seventh of the gem had been consumed in the process*. By washing out the contents of the retort with distilled water, and carefully collecting the powder suffered to subside in a covered glass jar, we have found that *in a second similar process* it yielded an amount of carbonic acid nearly as great as at first; and in like manner, in a *third trial*, we have found it still capable of giving milkiness to the lime-water.

In order to complete the oxidation at a single trial, it would be necessary to have the diamond still more finely comminuted, or to use a much larger amount of the oxidating agent than in the experiments here cited. The chief point of interest in the subject however is *the fact which we believe has now for the first time been shown, that diamond is capable of being oxidated in the liquid way, and at a comparatively moderate temperature, ranging between* 350 *and* 450 *degrees*.

On the Absorption of Carbonic Acid by Sulphuric Acid. *By* Professors R. E. *and* W. B. Rogers.

Notice of Pseudomorphous Crystals from Volcanic Districts of India. *By* J. Tennant, *F.G.S.*

On a Galvanometer. By W. S. Ward.

This was a modified form of an instrument exhibited at Oxford, in which a coil of wire conducting the electric current was suspended around the poles of a U-shaped permanent magnet. The coil had fixed upon it a small beam to which scales were attached: the improvement particularly described consisted in the length of the beam being so adjusted that the weights required to counterbalance the deflecting force gave the measure of the current in grains, corresponding to the number of grains of zinc per hour dissolved in each cell of the battery when a short coil was used, and corresponding to sixteen grains balanced by the electromotive force of one pair of Grove's elements when a long coil of fine wire was used.

On the Electromotive Force, Dynamic Effect and Resistance of various Voltaic Combinations. By W. S. Ward.

Tables were exhibited showing the results of measurements made with the galvanometer described in the paper previously read to the Section.

On the Chemical Composition of Gutta Percha. By Francis Whishaw, *C.E.*

GEOLOGY AND PHYSICAL GEOGRAPHY.

On Fossil Remains recently discovered in Bacon Hole, Gower; also other Remains from beneath the bed of the River Tawey. By Spence Bate.

The cave in which the fossil remains were found, to which allusion is chiefly made in the following paper, is formed by a fissure or fault in the mountain limestone. It is situated on the sea-coast, about 20 feet above high-water mark, on the western coast of the headland of Gower, and about nine miles from Swansea. It is upon the southern side of the anticlinal axis, which passes through Gower from a little to the north of the Worm's Head, through Cefn Brynn, crosses Caswell Bay, and loses itself in the sea at the back of the Mumble Head. The strike of the limestone in which the cave is situated is nearly north and south, with the dip to the east. The cave narrows rapidly from the mouth, but is 30 feet wide about the centre of the main channel. It is 128 feet long, and possesses evidence of having once been a great deal more extensive, since the rocks below its mouth are strewn with blocks and large masses of breccia, together with broken fragments of stalagmite, which must have fallen both from its roof and floor. The floor of the cave, from the extreme end where it is divided into two chambers, caused by the fault separating itself into two fissures, gradually rises towards the entrance, and in such a manner as to indicate that the mouth itself was at a time when the cave extended to a greater length blocked up, and argues that this could have been the only entrance which the cave ever possessed, and that no communication through the roof, as is sometimes found, could have existed by which the angular fragments now forming the bone-bed of the cave could have existed. Since in the bed of stones no stalagmite is found, and in the stalagmite not a single stone has become entangled, we may infer the introduction of the stones, together with the bones found amongst them, to have been a simultaneous injection, since which natural causes have quietly put a seal upon them. The elevation of the cave exceeds scarcely 12 feet at the highest point of the main cavern, where, as in the two inner chambers, it becomes much more lofty. This cave seems in itself to afford sufficient evidence that thickness of stalagmite is no proof of age, since the greatest thickness of carbonate of lime follows the line of the fissure throughout, being greatest where the two faults meet, in which place it attained a thickness of 2 feet and more, and required blasting for its removal; it decreases in substance gradually on either side and towards the entrance, where it in some places

scarcely exceeds an inch. This corresponds with the deposits of carbonate of lime in the roof, where the fault is choked up by the material, but which hang in no graceful stalagmites but unite in one large mass, except near the entrance, at which extremity a square original-shaped portion impends, which in the eye of the tradition of the neighbourhood has assumed the form of a flitch of bacon, hence the peculiar cognomen Bacon Hole, by which the cave is known. From the fault on either side the roof descends in a direct line until it meets the floor, forming a triangular entrance.

The most important remains which yet have been found in this cave consist of teeth of the ox, deer, and other ruminants, together with a portion of the cranium of a deer and a few bones of a bat; all the last save one were found in such close proximity as to lead fairly to the inference that they belonged to the same bird; and many other bones, the most of which seem to belong to the deer. Teeth of carnivorous animals were also found, among which were the left under canine of an old *Ursus spelæus*; also the canine and molar of a young bear of the same species; also a molar, the milk tooth, probably of a young hyæna.

At the same time were exhibited many specimens of antlers of the *Cervus elaphus*, and one probably of the moose deer; these are all attached to portions of the skull, affording evidence of having not been cast in the annual shedding season. These, together with a human skull, were discovered at the depth of six feet in the clay below the bed of the river Tawey.

On the Sources of the Nile in the Mountains of the Moon. By Dr. BEKE*.

This paper was in continuation of one 'On the Nile and its Tributaries,' read before the Royal Geographical Society of London during the Session of 1816–47, and printed in the 17th volume of that Society's Journal.

The author's hypothesis is, that the principal sources of the Nile, according to Ptolemy, are in the country of Mono-*Moézi*, near the east coast of Africa, and that the name "Mountains of the Moon," arose from the translation of the word *Moézi*, which signifies *moon* in the language of the Sawáhilis, or "dwellers on the coast," from whom the Greek merchants and seamen of Alexandria trading with India and Eastern Africa, obtained the particulars respecting the Upper Nile which are recorded by Ptolemy.

Dr. Beke exhibited two maps, showing the Nile and the east coast of Africa, the one according to Ptolemy, and the other according to his own hypothesis; and applying the positive knowledge possessed at the present day to the correction of the fundamental error of Ptolemy's map, namely its general extension much too far southwards, he inferred that the head of the Nile, which that geographer places on the western side of the country of the Anthropophagi, bordering on the Barbaricus Sinus, in the vicinity of the island of Menuthias, is most probably situate in about 2° S. lat. and 34° E. long., at the extreme eastern edge of the table-land of Eastern Africa, and at a distance of about 300 or 400 miles from the island of Zanzibar, which island he identified with Menuthias.

The author next showed how, in his opinion, Ptolemy fell into the very natural error of making the Mountains of the Moon extend from east to west across the continent of Africa, at right angles to the general direction of the course of the rivers flowing from them; whereas the actual direction of the eastern edge of the table-land, which to the Sawáhilis or natives of the coast has the appearance of an extensive range of lofty mountains, and which Dr. Beke identifies with the Mountains of the Moon, is from about S.W. to N.E.; and by measuring 600 miles in the latter direction —such being the distance that Ptolemy makes exist between the two heads of the Nile in those mountains—he hypothetically placed in about 7° N. lat. and 39° E. long., the source of that geographer's second arm of the river. This second arm Dr. Beke identifies with the Sobát, Telfi, or river of Habesh, which joins the Bahr el Abyad or White River in about 9° 20′ N. lat., and which was considered by the officers of the Egyptian exploring expeditions, who ascended it 80 miles, to contribute to the Nile nearly a moiety of its waters.

The author adverted particularly to the fact, that the confluence, at Khartúm in 15° 37′ N. lat., of the White and Blue Rivers—commonly but erroneously called the

* Printed *in extenso* in the Edinburgh New Philosophical Journal, vol. xlv. pp. 221–251.

White and Blue *Niles*—is merely the junction of the Astapus with the Nilus; and that, in reality, the confluence of Ptolemy's two arms of the Nile, namely the White River and the Sobât or River of Habesh, is in 9° 20′ N. lat., upwards of 6° beyond Khartúm; and while establishing that these two principal arms of that river have their sources at the extreme eastern edge of the table-land of Eastern Africa, he showed, further, the existence of a *third* great arm of the Nile, namely the Bahr el Ghazál or Keïláh, which joins the central stream from the west in about 9° 20′ N. lat., and which there is reason to regard as the Nile of Herodotus and other writers anterior to Ptolemy.

In conclusion, Dr. Beke called attention to the journey undertaken by Dr. Bialloblotzky into Eastern Africa, for the purpose of exploring the southern limits of the basin of the Nile; and he solicited subscriptions in support of this undertaking.

Addition by the Author.—The Rev. Mr. Rebmann, of the Church Missionary Society's East-Africa Mission, has lately sent home an account of a journey made by him into the interior. Within 200 miles due west from Mombás he came to the eastern edge of the table-land, which thus appears to be much nearer to the coast than I had been led to conclude. Directly before him Mr. Rebmann saw a lofty mountain, named Kilimandjáro, the summit of which is covered with perpetual snow. This mountain may be approximatively placed in 4° S. lat. and 36° E. long., and its elevation cannot well be less than about 20,000 feet. It is crossed by the road to the country of Mono-Moézi; and there is now scarcely room to doubt that it forms a portion of Ptolemy's Mountains of the Moon (Moézi), the *snows* of which are described by that geographer as being received into the lakes of the Nile. It is by proceeding into the interior in this direction that Dr. Bialloblotzky may be expected to discover the sources of that river.—See *Athenæum*, No. 1119, of the 7th inst.—April 14, 1849. [Mr. Rebmann's Journal, with a Map, is since published in the *Church Missionary Intelligencer* for May 1849, vol. i. p. 12 *et seq.*]

On the occurrence in the Tarentaise of certain species of Fossil Plants of the Carboniferous Period, associated in the same bed with Belemnites. By Mr. Charles Bunbury.

The fossil plants were stated to be in a very bad state for examination, being washed up together in a talcose schist, and often curiously distorted by the molecular action which the rock has undergone. In the Turin collections, Mr. Bunbury had made out nine species of Ferns, two Calamites, and three Asterophyllites, which he considered identical with Carboniferous species; a conclusion formerly stated by M. Adolphe Brongniart.

On a Boulder of Cannel Coal found in a vein of common bituminous Coal. By Starling Bengon *of Swansea.*

Whilst the shales and sandstones of the lower coal-measures of South Wales appear to have been for the most part deposited or formed in comparatively quiet water, the Pennant series of rocks above them, which are easily traceable throughout the coal-field from the greater hardness of their sandstones, contain frequent conglomerates of rolled pebbles of coal and ironstone, drifted plants, and occasionally small boulders of granite, with other proofs of drift to a considerable extent having occurred during their formation.

The boulder, which is 13 inches long, 7 wide, and 3 deep, was found in a seam of common bituminous coal at Penclawdd near Swansea, which is in geological position one of the lowest in the Pennant series. In the subjacent measures some seams of cannel coal are known to exist about 700 yards below the Penclawdd vein, and lying conformably with it. If the boulders and drift, which occur throughout the lower portion of the Pennant series, were derived from the subjacent coal-measures, it might have arisen from a partial destruction of the south-west portion of those measures during the formation of the Pennant rocks; and if the boulders of granite are, as supposed, equivalent to that of Pembrokeshire, they would also point to the same line of drift. The writer concluded by remarking, that if the suggestion is admitted that these boulders are derived from the lower measures of the same coal-field, the inference

would follow that sufficient time elapsed between the deposit of two successive veins to allow the perfect crystallization and formation of the lower one.

It also yielded information interesting with reference to the ascertaining of the manner of the formation of coal, as it would authorize an inference that the material of which in this instance the bituminous vein was formed, was originally too soft and yielding, notwithstanding its present hardness and density, to fracture the boulder during the period of pressure necessary for its formation; and also, that any mixture of gases or other ingredients acting or escaping during the formation of the bituminous coal, do not appear to have in any way affected the cannel coal deposited within it.

On the relative Position of the various Qualities of Coal in the South Wales Coal-Measures. By STARLING BENSON *of Swansea.*

The varieties of coal found in the mineral basin of South Wales may be classified under three heads:—

1. Bituminous; the small of which will coke.
2. Free-burning; which burns with rapidity, emits a considerable volume of flame, and is best adapted for steam purposes, but of which the small does not coke.
3. Stone coal and culm, or anthracite.

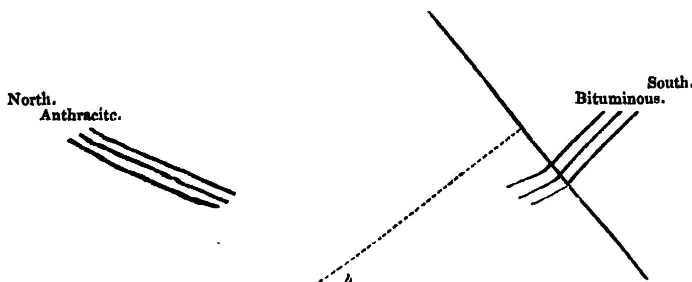
These three varieties are not suddenly altered as they approach each other; on the contrary, there is often a gradual change from bituminous to free-burning within the limits of the same colliery, whilst the free-burning coals would also appear to become culms, burning without flame, probably from the diminution of volatile matter, before the quality of the true anthracitic coal and culm is attained.

The annexed sketch of the coal-measures between Pontypool and Kidwelly will serve to illustrate the position of each variety of coal.

With a few exceptions, arising from portions of seams of coal removed from their original relative positions by faults or anticlinals, a central line of quality may be assumed to extend from Merthyr to Pembrey mountain near Llanelly; the bituminous veins of coal on the south gradually becoming less so until they are free-burning in the centre, whilst these again change into culms, burning without flame, until the true anthracitic coals and culms are found on the north crop.

Exclusive of the Pembrokeshire portion of the coal-measures, which is anthracitic, the area between Pontypool and Kidwelly, where both crops merge in the sea, may be estimated at fully 750 square miles, of which about $\frac{4}{15}$ths consist of stone-coal and culms, $\frac{11}{15}$ths of coking, smelting and free-burning coals.

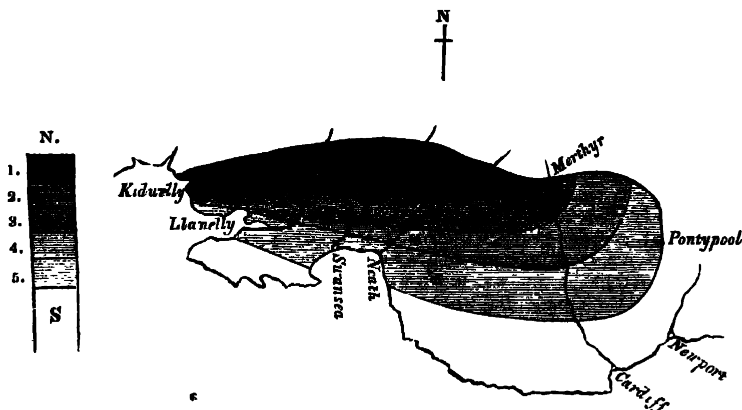
It is often remarked that each vein on the south crop gradually loses its bituminous quality as it dips to the north, but the more southern veins not so rapidly as those above them: and it has been suggested, that a line or plane *a* dipping to the south might be so placed as to intersect each vein at a point where its relative proportion of bituminous quality has disappeared.



Supposing anthracitic coal to be formed by the removal of certain volatile matter, chiefly oxygen, from bituminous coal by means of heat, may not a line, *b*, drawn at right angles to this intersecting plane, point to the direction whence such heat was derived from beneath the carboniferous measures? The surface-map, which shows that the seams of coal east of Merthyr are not anthracitic, but retain more of the bituminous

quality, would also imply that the source of heat lay rather to the north-west of the existing coal-field.

The existence of this variety of coals in the South Wales basin is an object of such interesting inquiry, that the writer ventured to offer these remarks in case they might in any way tend to assist in leading the minds of others to the discovery of a true solution of the cause.



1. Anthracite. 2. Culms. 3. Free-burning, gradually becoming 4 and 5. Bituminous.

Notice of a Map of Ancient Egypt of the Time of Antoninus Pius. By JOSEPH BONOMI.

It is divided into *Nomes* or provinces from C. Ptolemy's Geography, and contains the roads from the Roman Itinerary. Against the towns in the land of Goshen are written the Hebrew names from the Book of Exodus, which mark the march of the Israelites, and a reference to Isaiah, chap. xl. 15, explains that the head of the Red Sea had been separated by the sands since that interesting event, and left in the form of a lake. The Lake of Mœris is also laid down as discovered by Linant in 1843.

On the Discovery of some Remains of the Fossil Sepia in the Lias of Gloucestershire. By Prof. BUCKMAN, *F.G.S.*

Remains of the Belemnite and other animals allied to the recent Cuttlefish, abound in the lias formation, but the chambered portion of the Belemnite is seldom present, and the ink-bag of the Sepia is still more rare. One specimen discovered by Mr. Buckman in the lower lias is rather more than half the shell or "bone" of a Sepia, nine inches long and six inches wide; in the centre of the specimen is preserved the ink-bag, which consists of about six drachms of a jet-black, hard and splintery substance, easily ground down, and capable of being used as sepia or Indian-ink. Another specimen is four inches long and two inches wide, and is marked by three raised lines, which meet in a point at the base; the ink-bag is seen in the centre of this specimen also. They were obtained from a bed of fissile marl about four inches thick, in the upper lias near Cheltenham, along with plants, insects, Ammonites, and four species of fish, besides the uncinated arms of another fossil Cuttlefish.

On the Plants of the "Insect Limestone" of the Lower Lias. By Prof. BUCKMAN, *F.G.S.*

The band of limestone at the base of the lias is well known in Gloucestershire and the adjoining counties from its use in flooring barns and kitchens, and to the geologist

from having afforded abundance of insect remains, resembling those of ordinary occurrence in temperate climates. The plants associated with these insects at Strensham in Worcestershire are Ferns (*Otopteris*), Calamites, Confervæ, *Naidita lanceolata*, Brodie, Hippuris, and *Equisetum Brodiei*, Buckman. The ferns occur in fragments, and may have floated from some distance; the rest are small aquatic plants, which confirm the opinion that this limestone was deposited in an estuary, and in a temperate climate.

On some Experimental Borings in search of Coal. By Prof. BUCKMAN, *F.G.S.*

The first experiment was made four miles from Droitwich in Worcestershire, on an estate purchased by a gentleman mainly from belief in a prevalent tradition that coal had been found there many years before. Having sent into Staffordshire for some practical miners, a boring was made to the depth of 100 yards, and not being attended with success, Mr. Buckman was consulted, and by his advice the undertaking was abandoned. In this locality the lower lias approached closely to the experimental ground, so that, in order to reach the coal-measures, the whole thickness of the Keuper marls and new red sandstone must have been passed through.

A second attempt for coal was made near Malmsbury, Wilts, where former unsuccessful trials had been made, and where, as upon all Crown-lands, "mining rights" were reserved at sales! The formation at this place is Oxford clay, which occasionally contains small beds of *lignite*; a shaft had been carried to a depth of nearly 100 yards without getting below the Oxford clay, when Mr. Buckman was consulted, and the attempt given up.

On Marginopora and allied Structures. By Dr. CARPENTER.

On a Peculiarity in the Structure of one of the Fossil Sponges of the Chalk, Choanites Königi, *Mantell. By* WILLIAM CUNNINGTON.

The author requests attention to some peculiarities in the structure of those fossil sponge-like bodies of the chalk-formation to which Dr. Mantell, in his 'Geology of Sussex,' gives the name of *Choanites*.

He describes them as being of a subcylindrical form, with root-like processes, and having a cavity or sac which is deep and small in comparison with the bulk of the animal. The inner surface is studded with pores which are the terminal openings of tubes, disposed in a radiating manner, and ramifying through the mass.

"The species named by Mantell *C. Königi* is figured in the 'Geology of the South-East of England,' tab. 16, fig. 19 and 20. A partially decomposed specimen of one of these fossils, which I discovered some years ago, disclosed a long spiral canal winding round the siliceous cast of the central cavity. This I was at first disposed to think was the shell of a Serpula, but subsequent investigation, and the dissection of a large series, have convinced me that it forms part of the original fabric of the Choanite itself. It commences near the base of the central cavity, and quickly attaining its full diameter (about the eighth of an inch), it ascends with considerable regularity in a spiral direction, and terminates on the upper surface at a short distance from the centre. In large specimens there are as many as five or six volutions. Many of the tubes, which radiate from the central cavity, anastomose with the spiral canal, and an intimate connection is thus established between it and the other parts of the sponge. I have not found a similar structure in *Polypothecia*, *Hallirhoa*, or any of the allied genera which are associated with the *Choanites* in the chalk and chalk-flint. With regard to the purposes which this remarkable canal served in the economy of the animal, I can only conjecture that it may have been connected with the reproductive system, probably constituting the ovarium."

Reply to an Objection of Mr. Hopkins to the 'Chemical Theory of Volcanos,' contained in the last volume of the Transactions. By Dr. DAUBENY.

The difficulty in question, which, as Mr. Hopkins states, was first suggested by M. Gay-Lussac, has never, in his opinion, been explained away. It consists in

the supposed admission of air and water to the lower regions of the volcanic mass through fissures conducting the sea-water to the fluid lava; for supposing such fissures to exist, it would seem that the fluid matter below ought to ascend into them and fill them, provided the hydrostatic pressure at the bottom of each fissure was greater than the weight of the descending column of water, which must often happen, especially in such volcanos as Stromboli, in which the permanent position of the surface of the fluid mass is known to be at a great height above the level of the ocean.

In reply to this Dr. Daubeny remarks, that M. Gay-Lussac does not deny that water gains access to the focus of volcanos, but, on the contrary, asserts that the admission of water cannot be doubted, since no great eruption ever occurs that is not followed by the evolution of an enormous quantity of aqueous vapour, which, with that of the muriatic acid accompanying it, cannot be conceived to take place without an admission of sea-water to the interior of the volcano. The French philosopher, indeed, urged the difficulty alluded to only as militating against the notion of the interior of the earth being in an incandescent condition, and gives it as a reason for preferring the very theory which Mr. Hopkins impugns. The difficulty started, therefore, although it may call for explanation from mechanicians, cannot oblige us to reject the fact itself, established, as it is, on undeniable evidence; and all that chemists are concerned in is to speculate upon the consequences that might result from the admission of water to the interior of the earth, as Dr. Daubeny has attempted to do in his lately-published Work.

Nevertheless, it may be suggested, that the immense pressure exerted by a deep incumbent ocean, coupled with the resistance of a considerable thickness of solid rock intervening between its bottom and the focus of the volcanic operations, might oppose an obstacle to the ascent of lava sufficient to occasion lateral fissures, through which the melted matter would find an easier vent at some point on the contiguous land. It is true, that fissures of some sort must be supposed to have existed in the rock which the sea-water percolates, but these may readily be supposed to have been stopped up, at the commencement of each volcanic crisis, by injections of lava, which latter cooling in its progress upwards, would create an impediment to the further egress of melted matter by the same channels.

It may be observed, that volcanos do not occur in the vicinity of shallow seas, such as the German Ocean, and that many parts of the Mediterranean, near which active vents are found, are of great depth.

Nor is it necessary to suppose the elastic force equal to what would be required for elevating a column of lava to the summit of Etna or Teneriffe, but only such as might be adequate to produce the modern eruptions, which always take place from the flanks of these mountains; and this degree of elasticity, it is conceived, might be repressed by the weight of a deep sea, coupled with that of a considerable thickness of intervening rock, and thereby might determine the issue of the lava at some distant part.

The recurrence of eruptions Dr. Daubeny has always referred to the cracks occasioned by cooling in the incumbent rock, whereby a fresh ingress of water to the volcanic focus might be allowed. Be that however as it may, the fact of the presence of water stands unaffected by the truth or error of these attempts to account for the mode of its introduction.

Notice of Discoveries among the British Cystideæ, *made since the last Meeting. By* Prof. E. Forbes, *F.R.S.*

At Oxford Prof. Forbes had given an account of this group of fossils, considered by Baron von Buch as the lowest Radiate animals and representing the rudimentary forms of the superior orders, but believed by the author to be higher than the Crinoids, and leading up from them to the Starfishes and Sea-urchins. Since last year, a specimen formerly discovered by Dr. Bigsby in North America, and figured in the Zoological Journal, but mislaid, had been re-found, and proved to be a remarkable member of this tribe, having a globular body like a sea-urchin, with five depressions radiating from the oral aperture, in which arms were lodged; in the space between two of the arms was a circle of six ovarian plates. Another specimen very like this, but specifically distinct, had been discovered by the geological surveyors in the oldest Silurian rocks of Wales, showing that species provided with better arms than any other Cystideans appeared as early as the armless species. Some other species had

been discovered in a Silurian stratum in North America by Mr. Vanuxem, and described by the name of *Agelocrinites*. They were all provided with stems like the Sphæronite and Pseudo-crinite.

On the Polarity of Cleavage Planes, their conducting Power, and their Influence on Metalliferous Deposits. By EVAN HOPKINS, *C.E., F.G.S.*

The writer states that, taken *on a large scale*, "all the primary crystalline rocks, and the sedimentary beds in contact, have been more or less cloven in a direction approaching the meridian, and in planes but slightly varying from the perpendicular." These cleavage planes he compares with the structure of the medullary rays of a tree, the contortions of the schist he compares with the bending of the grain in the neighbourhood of knots, and the ascending sap is represented by "the polar current and the mineral solutions." An action, commencing in the moist crystalline granite, has formed, and still forms, this laminated and fibrous polar structure; the granite is transformed into gneiss, the gneiss into micaceous schist, and the termination of the crystalline transition into clay-slate. These great cleavage planes are the cause of the varying structure of the primary rocks, and give rise to the mistaken idea of their being sedimentary rocks subsequently thrown vertically. He says they are developed on a gigantic scale in South America; they cut the Isthmus of Panama transversely and extend into Mexico and the United States; and that the same phænomena have been observed in Scotland, and in fact in all Europe. He then compares the effects of the polar force with those produced in the magnetic battery, and states that he has seen masses of clay, in old mines and moist rocks, lodged in fissures acquire a cleavage identical with that of the bounding rock. He insists that *cleavage planes* must in every instance be developed in the *same direction as the internal molecular polar current*; and that the polar elongation of the crystalline rocks gives rise to tension, and consequently east and west fractures, thus producing mineral and other veins. The subterranean current in the semifluid mass always causes, according to the author's experiments, a westerly deflection of the magnetic needle. When sea-water is employed the variation amounts to about 10°. Hence *the direction of the conducting polar structure, or cleavage planes, will always be found to run N.E. of the undulating magnetic meridians.* After showing the important practical bearing of this subject on all questions connected with rocks, veins, minerals, dislocations, &c., the author concludes by stating, that "polarity of matter is the key by which we obtain a clue of the cause of the great changes which have taken place in the surface of the earth, and is the agent which is silently working within the crystalline film on which we exist; perpetually moving and modifying and rendering it suitable to our wants during all ages of transformation, and constantly providing inexhaustible stores of mineral wealth for successive generations."

On the Position of the Chloritic Marl or Phosphate of Lime Bed in the Isle of Wight. By Capt. L. L. BOSCAWEN IBBETSON, *K.R.E., F.G.S.*

In this communication the author pointed out the position of the chloritic marl or phosphate of lime bed in the Isle of Wight, and called the attention of the proprietors and farmers in the island to the importance of knowing the true position of this valuable manure. It is a gray marl full of green grains of a silicate of iron and fine quartz sand; it is very fossiliferous (the author appended a list of the fossils found in it in the Isle of Wight). The upper part of the bed forms in some places a conglomerate of pebbles and small boulders, and the fossils are broken as if rolled on a beach. The lower beds contain the fossils whole, and appear to have been formed in still water. *Ammonites varians*, *Am. splendens*, and *Scaphites striatus*, are the most characteristic fossils; but it also contains abundantly nodules of a coprolitic form, which Mr. Thomas Hetherington Henry has kindly examined, and finds they contain a large per-centage of phosphate of lime.

Mr. Austen mentions it being found near Guildford, and Mr. Nesbit has found it near Fareham, containing in the nodules 28 per cent. of phosphate of lime, and in the whole mass 2 to 3 per cent. Mr. Morris and the author have also found the chloritic marl very abundant at Chaldon near Lulworth, and also in the railway cutting of the

Wilts and Weymouth railway at Holywell. (The author mentioned the fossils obtained from these localities*.) The strata at Chute Farm consist of chloritic marl, but the fossils are more numerous and varied.

The general position of the chloritic marl in the Isle of Wight is as follows:—From Compton Bay along the south slope (adjoining the chalk marl) of Shalcomb, Mottestone, Brixton and Lammerstone Downs; near the farms of Compton, Coomb, Rancomb, Northcourt, Shorwell, Chillerton; between Chale Farm and Chillerton Down; largely developed near Gatcomb; between New-barn and Gausons on the Bridle road and hill between Gausons and Carisbrook; a great thickness on the road from Mount Joy to Whitcomb, near the farms of West Standen, Sullons and Arreton; the south slope of Arreton, Messley, Ashey, Brading, and Bembridge Downs; near the farms of Messley, Grove, Upper Martin and Yaverland; running into the sea near the Culver Cliff. The chloritic marl is also found on Shanklin, St. Boniface, Kew, Week, Appuldercoomb, St. Catherine's, and Niton Downs; at the top of the Undercliff, Ventnor Shute near Steep-hill Castle; in large blocks on the sea-shore, and also near the farms of Shanklin, Luccomb, Wroxhall, Winson, Span, Kew, Week, Dean, Little Stenbury, Sheep Wash, Niton and Chale, always immediately under the chalk marl, and separating it from the upper greensand. This chloritic marl or phosphate bed may be applied with great profit on the adjacent arid ferruginous sandy soil so common and unproductive in the centre of the south side of the island, viz. at Brixton, Chale, Kingston, Godshill, Newchurch, Bleak Down, Rookley, Queen's Bower, Sandy-way, &c. The drift or gravel beds of the island on the north side are composed of angular flints very little waterworn, and in some places perfectly sharp, and they are interstratified with a fine brown sand and marly brick earth. The sand and clays in which they are imbedded are the same; it has every appearance of being similar to the flint gravel in the neighbourhood of London, &c. The north side of St. George's Down is thickly covered with this gravel, but at the south end, beyond the greensand and gault, there is a thick bed of very hard flint and chert conglomerate. Strongly cemented with iron, it is stratified in places with zones of the broken ferruginous bands of the upper beds of the lower green sandstone, on which strata it is reposing; and the sands and clays in which they are imbedded are debris derived from the lower greensand. The whole of the drifts in the centre of the south side are the same but do not form conglomerates, but merely ferruginous flinty gravels stratified with ferruginous sands.

It appears from the above that the drift beds on the north side are the detritus derived from the flints of the chalk and sands and clays of the tertiary series, and do not appear to have been accumulated on a sea-beach, in consequence of the angular form presenting little evidence of their having been subjected to much attrition.

On the south side of the chalk range the drift has resulted from an admixture of chert and flints, probably from the upper greensand with the debris of the sands of the lower greensand, and appears to be local. The tops of the highest hills are not covered by this drift; on them we find only the angular or unrolled flints without any intermixture of sand or clay.

The author does not regard a vertical upward movement as the cause of the singular position of the chalk and tertiary beds, but conceives that slides occasioned by the decomposition of the fuller's-earth and the abrasion of soft sandstone by currents of water may have produced these effects.

Since writing the above paper, the author has found that Mr. Nesbit has analysed some of the strata, and found that a nodule in the lower chalk at St. Catherine's Down contained 19·00 per cent. phosphoric acid and 39·00 per cent. phosphate of lime, and that the upper greensand contains, on an average of twenty different specimens, 16 per cent. phosphoric acid and 25 per cent. of phosphate of lime.

Account of an extensive Mud-slide in the Island of Malta. *By* A. MILWARD.

The writer gives this account with the view of elucidating the motion of viscous

* *Note by Professor E. Forbes.*—Hitherto no species of Neæra, so far as I am aware, has been found in cretaceous strata. Capt. Ibbetson discovered a species of Neæra in the oolitic rocks, and several are known in the tertiary and recent formations. This cretaceous form supplies the deficient link in the series of Neæra in time.

bodies and the analogous phænomena of glaciers. Previous to the autumn of 1846, a large quantity of mud, dredged from the harbour of Valetta, was deposited on level ground between the harbour and cliff, and covered about two acres of ground; the autumnal rains, aided by the overflow of a tank on the cliff, caused the main body of the mud to flow from the side next the sea, where it was piled up highest, towards the cliff; the mud descended in streams whose inclinations were greatest at their origin, and their surface was marked by alternate curved bands of coarse and fine material, the rough bands being slightly in relief; where the descent was steepest, the curved bands were broken and irregular; as the surface of the mud dried, two sets of fissures were formed, one in the direction of the stream, the other following the curved bands. In the spring of the present year a smaller slide took place, in which the surface of the mud was raised into curved bands or waves 1½ to 2 feet high, the ridges being formed of the coarser materials. It appears that in the first instance the surface-mud was semi-fluid, and flowed over a comparatively dry and hardened surface, but afterwards the surface-mud dried by exposure, whilst that below remained moist.

An attempt to illustrate the Origin of "Dirt-bands" on Glaciers. By A. MILWARD.

The surface of a glacier is composed of alternate bands of porous and compact ice, and the former becoming discoloured more readily than the latter, give rise to "dirt-bands," which follow the direction of the hyperbolic curves marked by the outcrop of the structural planes, known as the "ribbon" structure, which are elongated low down the glacier and compressed near its source; they are also most apparent low down, where the ice has been longest exposed to the weather. The writer suggests that the porous bands may be formed during the winter season, when the ice is less saturated with water and forms more slowly; and that the compact bands mark the quantity of ice added to the glacier each summer, when its motion is greatest. He also recommends the examination of the upper part of glaciers, with the view of ascertaining whether their surface is originally marked by waves such as those before described on the mud-slides.

On some Bones found in the Bed of the Tawey. By W. MORGAN.

On the Subsidences which have taken place in the Mineral Basin of South Wales, between the Llynvi Valley on the East, and Penllergare on the West. By F. MOSES.

Mr. J. G. Jeffreys exhibited specimens of the following rare and recent British shells, and species which he considered identical with them in the Crag formation.

RECENT.	FOSSIL.
Buccinum ovum, *Turt.*	β Dalei, *Sow.*
Fusus scalariformis, *Gould.*	Id., *Sow.*
Saxicava arctica, var.?, *Forbes & Hanley.*	Sphenia cylindrica, *Sow.*
Natica helicoides, *Johnst.*	Id., *Sow.*
sordida, *Lam.*	N. cirriformis, *Wood.*

The Marquis of Northampton read a letter from M. Boguslawski on the fall of a Meteorite, in two pieces, at Braunau in Bohemia, on the 14th of July 1847. Another meteorite of larger size, but exactly agreeing in appearance and chemical composition, had been dug up from a depth of fourteen feet at See Læsgen.

On the Geology of the County of Wicklow. By Prof. OLDHAM, *M.R.I.A.*

This communication was illustrated by a new Geological Map of Wicklow and a number of sections in the mining districts, published in connection with the Geological Survey of Great Britain. Through the centre of the county passes the granite ridge, which extends from Dublin to Waterford, nearly N. and S.; its highest point,

Lugnaquilla, 3000 feet above the sea. On both flanks of the granite rests a series of sedimentary deposits whose general strike is N.E., dip S.E., and therefore oblique to the granite, which cuts them all in succession; the oldest of these rocks are at the north end of the east flank of the granite, and consist of sandy and slaty beds altogether from 4000 to 5000 feet thick ("Barmouth Sandstones"). These are followed by argillaceous beds, and volcanic ash and breccia with contemporaneous greenstone; a considerable number of fossils have been found in these beds, the equivalents of the lowest of all the Silurian remains in Wales. On the western flank of the granite only this upper series is found. Both series of sedimentary rocks have been upheaved, subjected to lateral pressure, contorted and fractured; besides which, they have all been altered along the line of contact with the granite to the extent of 5000 or 6000 feet, and over a breadth of half a mile on the surface; the influence of the formerly heated granite is shown in alteration of structure, and in the production of minerals not existing in the unaltered rock; in the conversion of sandstone into quartz-rock, and of the volcanic beds into a crystalline hornblendic rock. The dip of the slate, &c. is sometimes 70°, but usually much less; the granite extends under them, and is shown again at a distance by denudation; portions of the altered slate remain upon several summits of the granite hills, and show the original height of the surface of the granite, which in these points has been preserved from the rapid decomposition which has wasted it all around. The summit of Lugnaquilla is a mass of slate of this kind, traversed by numerous large veins of granite; similar veins pierce all the rocks in contact with the granite, and many of these, having taken the direction of the bedding of the rock, appear as if interstratified. In Glen-malur these granite veins may be seen extending with parallel edges for hundreds of feet. Besides these and the contemporaneous greenstones, there are numerous dikes like the Cornish *Elvans* in the southern and metalliferous part of the county; these never cut the older sedimentary rocks, but abound in the upper series. Glen-malur, in which several lodes of lead are worked, is formed by a great fault; and there are several other nearly parallel glens, some occupied by lakes; the Vale of Avoca is also caused by a fault which shifts all the lodes; these dislocations extend into the granite itself. In Wicklow there are no formations newer than the lower Silurian, except the drift; but a little westward the edges of the Silurian rock are covered by the conglomerates and sands of the Old Red system. The drift consists of clays and sand mixed with limestone boulders, which are scratched and furrowed; in some parts of it organic remains occur in such a manner as to prove they lived on the spot; some of the species however are Arctic, and occur 700 feet above the present level of the sea. In the northern part of the county the drift is gravelly and mixed with angular fragments of older rocks adjoining; huge blocks of granite and quartz-rock are strewed over the county, the lower surface occasionally retaining distinct scratches and furrows. The surface of the county appears to have undergone extensive denudations since the deposit of the drift, and many of the ravines and caldron-shaped hollows are quite free from drift.

On the Drainage of a Portion of Chat Moss. *By* G. W. Ormerod, *M.A., F.G.S.*

The *surface* of the moss varies from 80 to 100 feet above the sea-level; the *bottom* at the deepest part proved, is at least 100 feet below the sea-level. Part of this moss is now being laid dry by means of open drains, under the direction of M. Ormerod. After cutting the drains, the level of the peat falls rapidly; near the main leader it sunk perpendicularly 5 feet 6 inches in about nine months; and in one part 2 feet 6 inches in a single week.

Lieut.-Colonel Portlock communicated some observations on apparent changes in the level of the coast near Portsmouth, and contended that as these evidences of subsidence could be traced back to the most ancient times, so they had continued up to the present day, and expressed his conviction that a parallel might be found in existing nature to all the phænomena of ancient times. It appears that part of Fort Cumberland near Portsmouth stands on a bank of gravel and sand, and that owing to some new groins made to protect it from the sea, a fresh direction was given to the tide, and a portion of the bank undermined and washed away, in the course of which a thick

plank with a bolt was discovered, showing that this part of the bank had no great antiquity. An Artesian well has also been made to supply Block-house Fort, which for the first sixty feet exhibits nothing but clear shingle, and then a layer of sandy clay full of common oyster-shells, another example of the great changes in the ancient coast and sea-bottom.

Hydrography of the British Isles. By Augustus Petermann, *F.R.G.S.*

Mr. A. Petermann exhibited a new Hydrographic Map of the British Isles, on which about 1550 rivers are distinguished by names, 480 lakes and ponds, and 40 waterfalls; the canals with their altitude, as well as that of the rivers and lakes, and the great drains in the fen districts. It was stated that there are 20 rivers in England, 10 in Scotland, and 10 in Ireland, each draining 500 square miles and upwards.

Of these, 18 drain an area =	500	to	1000	sq. miles.
14	1000	„	2000	...
8	2000	„	10,000	...

These last eight are,—

The Humber (including Trent and Ouse), to Spurn Point...	9550 sq. miles.
Severn, to Flatholm Light	8580
Shannon, to Loop Head and Kerry Head	6946
Thames (including Medway), to Nore Light	6160
Barrow	3410
Great Ouse	2960
Bann	2345
Tay, as far as Rhynd	2250

The River Amazons drains a tract of 2,275,000 square miles.

On some points connected with the Physical Geology of the Silurian district between Builth and Pen-y-bont, Radnorshire. By Prof. Ramsay, *F.G.S.*

In this paper Professor Ramsay first laid down certain established geological propositions, on which much of the reasoning in the communication depended.

When a stratum rests unconformably on the upturned edges of another series of strata, the lower rocks were denuded, either previous to or during the deposition of the higher stratum, and we know of no power at any considerable depth beneath the level of the sea fitted to effect such phænomena, which therefore took place either above or *at* its surface.

In the district described (near Builth in Breconshire), the Wenlock shale rests unconformably on the Llandeilo flags, which there consist of black slates associated with beds of trap and volcanic ashes. These rocks having been disturbed and raised above the level of the sea, formed the land round which the lowest beds of the unconformable Wenlock shale were deposited, and gradually sinking beneath the level of the sea was covered up by higher Silurian strata, which accumulated above it to the vertical thickness of 5000 feet. A part at least of the old red sandstone was added to this, and during subsequent oscillations of level these higher rocks (beneath which the old land had been so long and deeply buried) were removed, and the Llandeilo flags of the district are now land for the second time.

The sections exhibited also afforded data, by which could be ascertained the angles of inclination of the Llandeilo flags at the time they lay under the Wenlock and other superincumbent beds, previous to the disturbance that raised these latter formations into an anticlinal curve, the lowest bed of which rested unconformably on the upturned and denuded edges of the Llandeilo flags.

They also indicated a method by which it may sometimes be possible to determine the vertical thickness of accumulations above certain other deposits, thus pointing to a means of forming a proximate idea of the degree of heat the latter may once have endured, supposing the same ratio of increase of temperature as we descend beneath the surface to have existed at that geological epoch that now obtains.

On the Geology of Pennsylvania. By Professor H. D. ROGERS.

Professor Rogers exhibited a general map of North America, the State Survey of Pennsylvania, and many other maps and sections coloured geologically.

1. After pointing out the general accordance in the succession of the older rocks in America with those of Europe, he stated that the rocks composing the great Appalachian chain had been deposited near the eastern shore of the Palæozoic Sea in North America, and detailed a variety of circumstances in evidence of the existence of an ancient continent in the direction of the Atlantic.

2. Amongst these hills there is a well-defined series of rocks, containing a succession of fossils; but further west, where the same strata spread out to an enormous extent (in Kentucky and Tennessee), we seem to have arrived at the deep-sea part of these formations, in which all distinctions melt away, and an uniform succession of sedimentary deposits have accumulated to a much greater thickness than near the coast. Wherever the tributaries of the Ohio, or the rivers of Virginia break through the hills, we find beds of grit diagonally stratified, with conglomerates and all other indications of a shallow sea; but passing westward the same beds become finer and finer, the conglomerate passing into grits and these into fine-grained sandstones. The carboniferous limestone, which is but a few feet thick in the Appalachian, becomes 500 feet thick in the Mississippi.

3. After the elevation of the greater part of this region, the sea still covered the whole of Florida, the great plains of Arkansas, and extended far up the Missouri, and along the Atlantic plain as far as New Jersey; over this area was deposited first the cretaceous series and afterwards the tertiary.

4. Between the tertiary plain and the Appalachian hills is a great tract of unfossiliferous rocks ("Azoic" and "Metamorphic"), at least 10,000 feet in thickness, and along their western boundary, for 100 or 150 miles, the *newer rocks all dip under them*. This extraordinary circumstance was first explained by Professor Rogers, who has shown that it is the result of the folding of the rocks. The Appalachian chain consists, in fact, of a series of parallel anticlinal and synclinal folds, all leaning over to the west, so much as to *invert* the series of beds on the west of each synclinal; these folds are steepest where they plunge beneath the azoic series, and open out gradually westward, until the strata become horizontal in the Ohio coal-field.

Professor Rogers then gave a summary of his theory of the origin of these great parallel foldings in the Appalachian strata, which he attributes to a series of earthquake movements, flowing forward in a particular direction in parallel lines; and he illustrated this view by a description of three remarkable earthquakes in the year 1833. The first, that of St. Domingo, was experienced by the officers of a British vessel at sea, who stated that looking at the coast they had seen "the crests of the hills waving like the back of a serpent in gentle motion;" these undulations had been traced along lines on which they were synchronous. 2. The earthquake in the Vale of the Mississippi, in which the lines of synchronous shock ranged N.N.E. and S.S.W. for 500 miles; at a parallel 300 miles east of the line the shock was experienced eight minutes later; and all along the Atlantic shore twenty minutes later. The sensation was not that of a harsh grating of subjacent rocks, but a billowy heave. 3. A few months later another earthquake affected the whole volcanic line of the Windward Isles and Bermuda simultaneously, and was attended by a sudden return to activity of some of the dormant craters; in the course of twenty-two minutes it had flowed to the United States, and rocked the whole coast from Florida to New York. All these phænomena were considered to prove the doctrine of a flexible crust resting on a fluid nucleus; and, as in former times, the crust may have been more flexible and the volcanic forces more energetic, the whole surface may have been thrown into billowy undulations, and there have become permanently fixed by the successive injection of lava into the craters and fissures of the various folds, thus preventing their return to horizontality.

5. The three great coal-fields of America are, that of the Ohio, 740 miles long, and 180 wide, covering an area of 63,000 square miles, a surface greater than that of England and Wales; the Illinois coal-field, covering 50,000 square miles; and the Michigan, occupying 15,000 square miles. Besides these, there are numerous anthracitic basins in Pennsylvania and Virginia, the furthest being 100 miles S.E. of the margin of the Ohio coal-field. In passing across these coal-fields there is a gradual diminu-

tion in the quantity of bituminous matter from W. to E. In the Illinois it amounts to 40 or 45 per cent.; in Western Ohio, from 35 to 40; in Eastern Ohio, 25 to 30; in the table-land of the Alleghanies it is reduced to 18 or 20 per cent.; in a little coal-field 20 miles E. of the great field it is only 14 or 15 per cent.; in the western edge of the anthracite field 10 or 12 per cent.; and in the great body of the anthracite only 1 or 2 per cent. of gaseous matter exists, and this not in the form of bitumen. Further south, in Kentucky and Tennessee, the same change takes place, and the associated rocks become metamorphic eastwards; all the coal, of every kind, rests on the same basis of rock, with the same fossils distributed through it, and the particular coal-beds can be identified even when separated by an interval of fifty miles. The anthracite field is 5000 feet deep, and contains fifty seams of coal; the bituminous coal-field of Ohio is 2800 feet deep. The working of these coal-fields is increasing rapidly; 3,000,000 tons of anthracite and 1,000,000 tons of bituminous coal are annually raised; and 700,000 tons of iron manufactured. A process for melting iron-ore with anthracite was long wanted, and the government of Pennsylvania had offered a premium for such a discovery; this was first achieved by Mr. Crane, in South Wales, by whom a patent was obtained in England; and for the use of it in America one iron-master guaranteed him a premium on all the ore melted; but for want of an international patent-right, the process was soon imitated, and in some cases improved upon, by other parties in America.

Drawings were exhibited of the anthracite coal-mines on the Lehigh-river, Pennsylvania, which are worked like an open quarry on the slope of a mountain rising 900 feet above the river; the coal is sixty feet thick, and surrounds the quarry in black glistening walls, capped by forty feet of yellow sandstone; it is conveyed by a self-acting railway for eight miles down a declivity of from 100 to 140 feet per mile; the whole cost of obtaining it being *2d.* a ton. This great bed of coal splits up into a number of divisions when quarried at some distance.

6. Professor Rogers then alluded to the subject of the drift, which had received new interest in America from the visit of M. Agassiz. This deposit is spread over the whole of the States and extends westward to the Upper Missouri; when it rests upon the older strata its *floor* is worn and striated with furrows, which follow the pre-established contour of the surface, diverging when they meet any obstacle, and coalescing on the further side; their general direction is N. and S. This drift is strewed indiscriminately over all the high ground as well as the valleys; neither the White Mountains in New York, 6000 feet high, nor those between Lake Champlain and the St. Lawrence, 5000 or 6000 feet high, being centres from which the drift was dispersed. Besides this general drift, with its boulders, there are long trains of angular masses of rock running N. by W. and S. by E. on the borders of New York and Massachussetts, derived from great ragged chasms in the summits of the Alleghanies 1000 feet above the plain. These angular blocks rest upon the surface of the drift, which overspreads the country to the depth of twenty or thirty feet; they vary in size from that of a hogshead to a small house, one of them being fifty feet long, and they do not much diminish in size from N. to S. One of these trains has been traced to a distance of fifty miles, another parallel line at a distance of half a mile is twenty miles long, and there are various others; they are about 200 yards wide, and the blocks are not in contact, but lie a little apart. They are not strewed like *moraines* along the flanks of hills, but pass alike over mountain and valley, climbing summits higher than that from which they originated.

Observations on the Great Anticlinal Line of the Mineral Basin of South Wales. By William Price Struvé, *C.E.*

The object of the few observations which I have to offer on this subject, is to describe the great central uprise of the coal-measures in Glamorganshire, between the Vale of Taff and the estuary of the Burry, in Carmarthen Bay.

In doing so, I will at the same time mention some of the governing features of the South Wales coal-field, confining myself principally to that portion of it situated between the Taff Valley and Carmarthen Bay.

This district comprises Glamorganshire and portions of the counties of Carmarthen and Brecon, and occupies an area of about 560 square miles. It is intersected by six

principal valleys, down which the mineral produce is conveyed by canal or railway to the several ports of Cardiff, Porthcawl, Port Talbot, Neath, Swansea, and Llanelly.

In order that the remarks which I have to offer may be brief and intelligible, I have prepared, from my own notes and the information supplied by the Geological Survey of Great Britain, seven sectional representations of the coal-field in the district alluded to, and shall at once refer to them for a description of the stratification.

The base of our coal-measures is carboniferous limestone, which, it will be observed, is basin-shaped, having a general rise from its centre towards the north and south, to which all the coal-measures conform: and they may be described as consisting of the following convenient divisions:—

	Mine. Ft.	Mine. In.	Black Band. In.	Coal. Ft.
First.—The Farewell Rock or Millstone Grit, containing no coal, and averaging a thickness of	400			
Secondly.—Argillaceous and arenaceous shales with some beds of sandstones	360	36		
Thirdly.—Strata of a similar nature, containing several seams of coal, some of which are very thick, and associated with mine, and are extensively worked at all the great iron-works	540	12	...	43
Fourthly.—A similar stratification, but with some thick beds of quartz rocks, called the Cockshuts, particularly well seen along the anticlinal line between Cwm Avon and Maesteg, and regarded by the miner as sure guides to some of the accompanying rich coal beds	420	12	...	3
Fifthly.—Arenaceous and argillaceous shales, with occasional beds of sandstones, and containing black bands, worked extensively at Cwm Avon and Maesteg, and lately discovered at the Ystalyfera Iron-Works	540	...	18 to 36	11
Sixthly.—A great accumulation of sandstones called the Pennant Rock, intermixed occasionally with some argillaceous shale, represented in this neighbourhood by the Kilvey and Town Hills, measuring in thickness	3000	...	...	7
Seventh and last division, containing shales and some thick masses of sandstone, and measuring about	3000	...	...	37
Making a total average thickness of	8260	60	36	101

In this statement I have only included the workable seams of coal and mine, my object being to convey a correct impression as to the available portion of the South Wales coal-field; and in order that the geological arrangement of these divisions may be easily understood, I have distinguished them on the sections by various shades of colour.

[The section was here explained.]

An important governing feature of the coal-field is the Pennant Rock, its outcrop being nearly as well marked as that of the carboniferous limestone. It may be traced in nearly its whole thickness from Swansea to Carmarthen Bay on the west, and eastward towards Briton-Ferry, Margam, Llantrissent, round by Pontypool, back to Merthyr, and across the tops of the valleys to Pembrey, where it again disappears under Carmarthen Bay.

On inspecting the Section No. 1, from Hirwain to Llantrissent, it will be observed that the lower portion only of this deposit caps the hills about the Rhonddas, and that it then bends over towards Llantrissent, accumulating the whole of its thickness, and bringing in the Dyhewydd seams, which may be considered equivalent to Hughes's seam, near Swansea, or to the commencement of the highest division of that coal-field. The denudation from the Rhondda of this thick deposit of sandstone removes, as it were, an impermeable cover, which, in other portions of the district where it is found to prevail in its full thickness, must serve as a seal to shut out for ever from the uses of man the lower thick beds of coal and mine so extensively worked along the margin of the coal-field; whereas, in this locality, they lie within an attainable depth for mining, and as flat as can be desired by the miner.

The next Section, numbered 2, crosses Llangeinor Mountain; here the Pennant Rock accumulates considerably. It is, however, broken through at Maesteg, which lies one mile to the west, by the central uprise of the coal-measures; the lower division of which is brought up to the surface, and worked extensively for the supply of three large iron-works. As we proceed more to the westward and approach the eastern confines of the Swansea Bay, the Pennant Rock becomes more extensively broken through, so that the whole of the lower measures are brought to view, and workings of a most extensive kind have been opened upon them for the supply of a large iron-works, rolling-mills, tin-plate-mills and copper-works.

On inspecting Section No. 3, it will be observed that the Pennant Rock stands on the north and south side of Cwm Avon, and that the lower measures must necessarily pass under Margam Mountain and crop out towards the sea. In conformity with this theory, pits are now being sunk in the neighbourhood of Port Talbot.

The next Section to which I shall refer is No. 5, from Caswell Bay, in Gower, to the Great Mountain, in Carmarthenshire, constructed by Mr. Logan and myself, and published in the Geological Survey. It will now be observed that the uprise has completely removed the continuation of the southern portion of the coal-field which exists between Margam and Llantrissent, and the limestone only is to be seen torn up and contorted in the manner described in the section. Proceeding still more westward through Gower, the limestone is found completely broken up, and the old red sandstone protrudes through from beneath, which is illustrated in Section No. 6, constructed by Mr. Logan, and which shows a small portion of the lower shales reposing on the limestone at the western side of Oxwich Bay.

Section No. 4, also constructed by Mr. Logan, from Port Tennant to Castle Cerig Cennen, is introduced for the purpose of illustrating, by an addition which I have made to the section, the probable partial removal of the coal-measures under Swansea Bay.

It would appear, therefore, that the great central uprise of our coal-field, which has served so usefully to bring up the lower coal-shales in various portions of it, is merely a continuation of what has acted with so much more violence in Gower; and that this movement may perhaps be traced back into Pembrokeshire, where, from the evidence afforded by Sir Henry de la Beche's valuable surveys, it appears that a great disturbance in the limestone and old red sandstone has also taken place.

I shall now close these remarks by some general observations. The annexed sections describe, with sufficient accuracy for general purposes, the governing features of the South Wales coal-field; which, from the description I have given, has been shown to contain enormous mineral wealth. Section No. 1, for instance, exhibits 57 feet thick of workable coal; 60 inches of workable argillaceous mine; and from 18 to 36 inches of black band, all within an attainable depth, averaging a distance by the Taff Vale Railway of about 20 miles from the port of Cardiff. One square mile of such a coal-field ought to produce, according to ordinary calculations, 40,000,000 tons of coal, 8,000,000 tons of mine, and 3,000,000 tons of black band.

The Swansea Section contains the coal-measures above the Pennant Rock, which may be estimated at 25,000,000 tons of coal per square mile; and to this may be added the last estimate for the coal and mine below the Pennant, which is available for many square miles at the tops of the valleys, where they are found to crop out in proximity with the limestone, and on which all the great iron-works of South Wales are established.

The extent of coal-field, therefore, which may be considered available chiefly to the ports of Swansea and Cardiff, may be estimated at about 400 square miles. The South Wales Railway will pass at the foot of all the valleys, so that on its completion the whole extent of this country will be in a condition, with the aid of short branches, to send its produce to either of these ports.

As regards the qualities of the coals, they may be classed in the following order:— bituminous coal, free-burning coal, culm, anthracitic culm, anthracite: for all of which there is an extensive consumption. The boundaries of these various qualities I have endeavoured to sketch out on the annexed sections.

The bituminous and free-burning coal appear to occupy the largest portion of the coal-field, and the anthracite and anthracitic culm the least. The anthracite commences slightly at Hirwain, and increases as it advances into Carmarthenshire; and in Pembrokeshire the whole of the coal-field partakes of that quality. The other

qualities take a similar direction, and gradually and imperceptibly pass into each other till they become bituminous coals on the south side of the coal-field.

Remarks on the Sources of the White Nile. By FERDINAND WERNE, *late attached to the Expedition sent by Mohammed Ali Pasha to explore the Nile (communicated by* Sir ROBERT H. SCHOMBURGK, *K.R.E.)**.

The author distinctly contradicted the discovery, recently announced to have been made by M. Antoine d'Abbadie, of the source of the Nile in 7° 49′ N. lat. and 34° 38′ long. E. from Paris. In 1840-41, the Egyptian expedition to which M. Werne belonged, ascended the main stream of the Nile as far as the country of Bari, in the fourth degree of north latitude, and they were there told by the natives that *the sources of the Nile lie still further to the south.*

From the formation and direction of the mountains whose valleys are watered by the Nile, an eye-witness would at once infer that the river comes from a distance of several degrees further south; and Lakono, the king of Bari, and his people invariably pointed to the south when describing the situation of the sources of the river. The European officers of the expedition arrived in Bari with the preconceived opinion that the Nile came from the east, and they were, in consequence, the more precise and careful in their inquiries respecting its source; but by no means could they induce the natives to deviate from their original statement that the river comes from the south.

Lakono himself, who asserted that he had been to the country of Anyán (Anjan) in which the head streams of the Nile have their origin, said that the water in the four rivulets whose confluence forms the main stream, came only to his ankles; and as, above the extreme point reached by the expedition, the river comes direct from among the mountains in the south in the form of a turbulent stream, running between steep banks and over a rocky bed; and as, further up, the declivity of its bed is apparently much greater; M. Werne regarded it as physically impossible that M. d'Abbadie's alleged source should be that of the Nile. In his opinion, M. d'Abbadie's river is a tributary either of the Blue River or of the Sobát; and he expressed his conviction that Ptolemy and the natives of Bari will be found to be correct in their statements respecting the position of the sources of the Nile, and that those sources are in the regions near the equator, where we shall also find the Mountains of the Moon.

The Dean of Westminster read a letter from the Rev. Dr. Moberley, describing a large Plesiosaurus discovered in lias at the alum-works of Lord Mulgrave at Kettleness near Whitby: length of the head, 3 feet 2 inches; neck, 5 feet 10 inches; back, 7 feet 1 inch; tail, 6 feet 10 inches; total, 22 feet 11 inches. Width of anterior paddles nearly 13 feet.

The Dean of Westminster exhibited a Map of part of North Wales, and sketches of rocks in the valleys around Snowdon, and pointed out the various indications of the former existence of glaciers in these valleys. One of the best localities for observing the effect of the moving masses of ice which formerly occupied the seven valleys that descend from Snowdon, is at Pont Aberglaslyn near Bedd-gelert. Near Capel Cerig also there is a great extent of naked rock exhibiting the effects of glacial action. The most obvious exposures of the effects of ice are in the valley of Llanberris and in the valley of Nant-Francan. Moraines occur on the margin of Llyn Ogwyn and of Llyn Idwell, having been forced across these lakes when filled with ice. In all these valleys the surface of the rocks below the superficial soil is rounded, furrowed and striated in directions parallel to the sides of each valley. At Llyn-y-Gader near Bedd-gelert there were very remarkable naked, round-topped hillocks, worn and smoothed by friction of the ice.

The Dean then gave an account of the principal phænomena of glacial action in Switzerland, where they are believed to have formerly extended very much further than at present.

* Since published, by M. Werne, in an appendix to his work, 'Expedition zur Entdeckung der Quellen des Weissen Nil,' 8vo. Berlin, 1848. An English translation of this work, by Mr. C. W. O'Reilly, has also been published in 2 vols. 8vo; London, 1849.

Supplemental Notice on the Geology of Lundy Island. By the Rev. D. WILLIAMS, *F.G.S.*

In a former notice the author described some remarkable dykes in the slate and granite of this island, and now exhibited a series of rock specimens showing every intermediate condition between true granite and trap by the gradual introduction of hornblende and lime. These specimens were obtained at the junction of the granite with the slate rock at the south-east and south of the island. The author called attention to the abundance of carbonate of lime in some of the primary rocks, from which he believed it had in many instances been dispelled by heat.

On the Geology of portions of South Wales, Gloucestershire and Somersetshire. By Sir H. T. DE LA BECHE, *F.R.S.*

ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

On the recent Species of Odostomia, a Genus of Gasteropodous Mollusks inhabiting the Seas of Great Britain and Ireland. By J. G. JEFFREYS, *F.R.S., F.L.S.*

THE author, after a few preliminary remarks, gave an historical account of the genus, and proposed the coalition of all the species now composing the separate genera of *Odostomia, Chemnitzia* and *Eulimella,* in one genus, treating the others as subgenera; and he founded this view upon his observations of the animals, as well as on the shells, of each of those so-called genera. After describing the characters and habits of these mollusks, he gave a synoptical view of the species, thirty-two in number; of these, nine (viz. *notata, alba, dubia, acuta, diaphana, dolioliformis, fenestrata, clathrata* and *formosa*) he described for the first time. The author then proceeded to an elucidation of their synonymy, which was previously in a state of confusion, and the following is the result of his researches:—Out of the thirty-two species enumerated and described by him, nine were new and hitherto unpublished; nine had been described and figured by Philippi as Sicilian shells; one by Recluz as French; ten by Lovén as inhabiting the Scandinavian coasts; seven by Searles Wood as crag fossils; and one (for which the author proposed to restore the Linnean name of *lactea* for *elegantissima*) as indigenous to the middle and south of Europe.

(This paper is published entire in the Annals of Natural History for 1848.)

On the Os humero-capsulare of the Ornithorhynchus. By Prof. OWEN, *M.D., F.R.S.*

He referred to the discovery by Prof. Nitzsch of a small accessory bone articulated to the coracoid and humerus in certain birds, called 'os humero-capsulare,' and stated that he had discovered an ossicle attached to the head of the humerus and to the capsule of the shoulder-joint of the *Ornithorhynchus paradoxus.* It was equally distinct from the proximal epiphysis forming the head of the bone, and from that which caps the great tuberosity in the young animal, and it was present in full-grown *Ornithorhynchi.* It appeared to have escaped the notice of Meckel, and although but a small instance of resemblance to birds, was interesting as an additional illustration of the affinities of the paradoxical mammal.

On the Communications between the Tympanum and Palate in the Crocodiles. By Prof. OWEN, *M.D., F.R.S.*

Prof. Owen referred to the discrepancy in the opinions of anatomists relative to the small perforation in the basisphenoid behind the posterior aperture of the nostrils in the crocodiles. It was called 'arterial foramen' by Cuvier in his 'Ossemens Fossiles,' and was described in the 'Leçons d'Anat. Comparée, 1836,' as "leading to a canal which bifurcated as it ascended, one branch traversing the sphenoid, the other the occipital to terminate in the ear-chamber;" but what passes through it,

or where the sphenoidal branch terminated, was not stated. Prof. Bronn had contended that this so-called 'arterial perforation' was the posterior aperture of the nostrils in certain fossil crocodiles, and had cited a letter from M. de Blainville expressing that anatomist's conviction of the accuracy of this view.

Prof. Owen stated that two short grooves converged, from without inwards and from above downwards, to terminate in the fossa behind the true posterior nares, in which fossa the median aperture in question was situated; both that aperture and those grooves led upwards to canals which conveyed air from the mouth to the ear-chambers. The canal from the median aperture divides into an anterior (sphenoidal) and a posterior (occipital) branch, and each of these divisions bifurcates to the right and left to communicate with the tympanic cavities; the occipital bifurcations also communicate with the beginning of two other eustachian canals, extending from the tympanic cavities to the lower lateral apertures and grooves converging to the common median perforation. All these canals open by a common median orifice upon the soft palate behind the true posterior nostril. The carotid canals commence by foramina situated one in each exoccipital bone external to the base of the condyle, and open also into the tympanic cavities, through which the arteries pass to enter bony canals leading from those cavities to the sella turcica. Examination of the soft parts in crocodiles and alligators that had died in the Zoological Gardens, and of the skulls of these and of the gavial, had confirmed the correctness of the description of the median foramen in question, as the "common terminal canal of the eustachian tubes," given in a former 'Report' by the author. (Reports of British Association, 1841, p. 76.)

With regard to the homologies of the above-described complex palato-tympanic air-passages in the Crocodilia, Prof. Owen stated that the lateral bony canals terminating in the common median fossa by distinct fissures, answer to the simple eustachian tubes of chelonians and lacertians, and the median canal with its dichotomy into four tubes, would seem to be a peculiar superaddition to the palato-tympanic air-passages in the crocodilian order.

Note on Sounds emitted by Mollusca. By Lieut.-Col. Portlock, *F.R.S.*

I think it right to draw attention to the *Helix aperta*, which is very remarkable for its property of emitting, when irritated, a strong and well-marked sound. When I first noticed the sound thus emitted on accidentally touching the animal, I was peculiarly struck by it and immediately referred to Rossmäesler, who I found describes the quality of the animal in a very graphic manner, stating that the sounds were such as indicated irritation. The *Helix aperta* is very abundant at Corfu, appearing thickly on the squill leaves in the spring, when about the beginning of March the annual increment of growth of the shell is perfectly soft. If the animal be irritated by a touch with a piece of straw or other light material, it emits a distinctly audible sound possessing a singular grumbling or querulous tone. This it frequently repeats if freshly touched, and continues so to do for apparently an unlimited space of time, as I kept one for a considerable time in my house, and heard this sound whenever I touched it.

As Rossmäesler has so fully described this fact, I shall only add that I have, on more occasions than one, heard what I considered a similar, though very feeble sound from the *Helix aspersa*, and I need not say that the explanation seems very easy from the structure of the animal.

On a new Species of Argonaut, A. Owenii, *with some Observations on the* A. gondola, *Dillwyn. By* Lovell Reeve, *F.L.S.*

Among the Argonauts captured by Sir Edward Belcher during the voyage of the Samarang, are two species, one distinct from any hitherto described, the other identical with a species, *A. gondola*, described upwards of thirty years since by the president of the Section, Mr. Dillwyn, in his 'Descriptive Catalogue of Shells,' but which had been disposed of by subsequent writers as a variety or immature state of the *A. hians* or *tuberculosa*. Specimens of each species were taken alive in the Atlantic by means of a gauze net at night. Drawings of the animal were exhibited made by

Mr. Adams from the living animal at the time of its capture; and the author had satisfactorily identified Mr. Dillwyn's species by means of these and other specimens in different stages of growth, collected by Mr. Cuming in the seas adjacent to the Philippine islands. The *A. Owenii* is distinguished from any species hitherto described by its laterally compressed form and prominent development of the wrinkles. The *A. gondola* is chiefly remarkable on account of the wide prolongation of the auricles on either side of the spire, whilst the keel of the shell is unusually wide, with the tubercles distant and more compressed. The lateral wrinkles are much less numerous than in *A. tuberculosa*, to which Mr. Dillwyn's species had been ascribed, and do not fade into solitary warts.

On the Influence of Temperature upon the Distribution of the Fauna in the Ægean Sea. By Lieut. Spratt, *R.N.*

After the publication, by the British Association, of the highly interesting report of the distribution of the fauna of the Ægean by Professor Forbes, I was led to imagine that temperature might have a great influence on that distribution: with this view I pursued the inquiry by making observations on the temperature of each region, as opportunities offered for doing so, whilst employed on the survey of the Ægean seas during the summer seasons.

These results seem to show distinctly that temperature is the principal influence which governs the distribution of the marine fauna.

The summer temperature of the air in the Mediterranean is about 86°, and the surface temperature reaches nearly that temperature generally at that season.

The zones of depth, as arranged by Professor Forbes, are as follows.—The first region includes all between the surface and the depth of 2 fathoms; but this he subdivides into a superficial or tidal zone of about 2 feet, the inhabitants of which, he observes, are remarkable as being such as have a wide range in depth, eight out of the eleven species peculiar to it being widely distributed in the Atlantic. The temperature of this zone ranges from 76° to 84° during eight months in the year. Its inhabitants are consequently subject to great vicissitudes of climate during the summer and winter. Nature having thus adapted them to these conditions, we consequently find that they are wanderers through great geographic space, corresponding to the vicissitudes of temperature to which they are subject.

The second region reaches to the depth of 10 fathoms, in which, with the last subdivision of the first region, we have, says Professor Forbes, the characteristic fauna of the Mediterranean. Now the temperature in this region is seldom lower than 74° in the long summer season, and it is consequently the region upon which the Mediterranean temperature has a more permanent influence; for which reason we find in it the peculiar Mediterranean fauna.

The third region descends to 20 fathoms, and has a decreased temperature to 68°; in the fourth region it is 62° at the depth of 35 fathoms; in the sixth region the temperature is 56° at the depth of 75 fathoms; and in the seventh and eighth regions, to the depth of 300 fathoms, the temperature decreases only to 55 or 55½°, as far as I was able to ascertain. Thus between the littoral zone and the lowest region there is a difference during summer of 26° and sometimes of 30°; and between the second region (the Mediterranean) and the lowest, the temperature is about 20°, thus standing at the average temperature of a high northern latitude. After limiting the Mediterranean fauna to the second region, Professor Forbes remarks that the third is a transition zone; but in the fourth region the Celtic character of the fauna is remarkable, there being in that region nearly 50 per cent. of species identical of northern forms.

In the sixth and lower regions he remarks, that although the identical Celtic species were fewer in the lower region, "he found the representations of northern species so great as to give a much more boreal or sub-boreal character than is present in those regions where identical forms are more abundant."

Amongst the Ægean fauna are some which have a wide range in depth, there being nine species common to six regions, seventeen to five regions, and two common to all, more than one-half of which are *known* to be wide geographic rangers. They, like the cosmopolite species of the littoral tidal zones, being thus adapted to climatal changes, become consequently ramblers over wide geographic space, as they

ramble into representations of climate in regions of depth. Thus we have the climate of a parallel represented in marine depths as in terrestrial elevation, and thus it appears that density or depth is not so great an antagonist to the existence of animal life as is generally supposed.

The greatest depth at which I have procured animal life is from 390 fathoms; but I believe that it exists much lower, although the general character of the Ægean is to limit to 300 fathoms; but as in the deserts we have an oasis, so in the great depths of 300, 400, and perhaps 500 fathoms, we may have an oasis of animal life amidst the barren fields of yellow clay, dependent upon favourable and perhaps accidental conditions, such as the growth of nullipore, now found to be a vegetable instead of a coral, thus presenting prolific spots favourable for the existence and growth of animal life. These peculiar conditions of density and food develope necessarily a peculiar fauna, upon which climatal influence nevertheless stamps its characteristic forms throughout the species.

Notice of an Observation at Bathcaloa, Ceylon, on the Sounds emitted by Mollusca. By T. L. Taylor.

"There is a curious thing here which I don't know whether you ever heard of. Going at night on the lake in the neighbourhood of the fort, one is struck by a loud musical noise proceeding from the bottom of the water. It is caused by multitudes of some animal inhabiting shells, I believe; at least the natives call them the 'Singing Shells,' and I have been shown what they said were those which made the noise. Some people doubt, however, whether it is these shells that sing, or some others, or fish of some kind. Whatever it be, I can answer for having heard the sounds repeatedly, so distinctly too that you cannot help hearing them even when the oars and paddles are splashing, and the boat going fast through the water. The sounds are like those of an accordion or Æolian harp, guitar or such-like vibrating notes, and pitched in different keys."

Cases of impaired Vision in which Objects appear much smaller than natural. By A. Waller, *M.D.*

This paper contained some observations of impaired vision in which the principal symptom consisted of an altered appreciation of the sizes of external objects. They were presented for the purpose of elucidating the action of the nerves and of the mind in the judgement of the dimensions of objects. In one case the illusion existed in one eye only, which perceived objects much smaller than the other. In other cases the illusion in both eyes was temporary, merely lasting for a few minutes at a time during the day, and then suddenly disappearing.

On the Luminous Spectra excited by Pressure on the Retina and their application to the Diagnosis of the Affections of the Retina and its appendages. By A. Waller, *M.D.*

These observations relate to the luminous spectra which appear in the field of vision when the eyeball is compressed, or when the head has received a sharp blow, and in various other circumstances. After having described the discoveries of Sir Isaac Newton and others, the author goes on to relate his own observations, and finds that these spectra vary according to the part of the eyeball which is compressed. If compressed at the upper part, they appear to be most bright, and consist of several concentric rings alternately bright and dark. He shows that these spectra may be employed with great advantage as a means of discriminating the diseases of the retina and optic nerve from those which affect the crystalline lens, the iris, and the other parts in front of the retina. In amaurosis, glaucoma and other affections of the nervous parts, the spectra are found to become more faint in proportion as the nervous powers are injured, and are entirely absent when the visual powers are more deeply impaired. On the other hand, in those numerous affections of the eye where the rays of light can no longer form their images on the retina on account of the opacity of the parts which they have to traverse, the ocular spectra are found to be

unimpaired in their brightness. The author has cited numerous cases in confirmation of this statement.

Microscopic Observations on the Movement of the Human Blood in the Capillaries, and on the Structure of the Nerves in the Glands at the Inferior Surface of the Tongue. By A. WALLER, *M.D.*

The author describes some microscopic observations on the minute glands at the inferior surface of the tongue. These minute glands, of about the size of a pin's head, are removed by him from the living tongue, and immediately subjected to observation under the microscope, for which, by their transparent nature, they are particularly adapted. He states, that by this means he has been enabled to discover several points relating to the structure of glands which cannot be observed in these tissues after death. The movement of the blood through the capillaries is there seen for the first time, and is found to present all the same phænomena as in the web of the frog or other transparent tissues. The nerves distributed to the various cells of which the gland consists are very numerous, and may be traced to the extremities of the separate cells, where they terminate, some in free extremities, others in vesicles, whose diameter is several times larger than that of the nerve-tube itself. Near their union with the glandular duct is a small ganglion which contains the usual elements, viz. vesicular globules and gelatinous and tubular fibres.

On the Structure and Functions of the Branchial Organs of the Annelida and Crustacea; illustrated by Preparations and Diagrams. By THOMAS WILLIAMS, *M.D.*

The subject was treated under the following heads:—

Explanation of a series of diagrams illustrating the history of ciliated epithelium in invertebrate animals.

New observations proving the presence of ciliated epithelium in the lungs of reptiles. Conclusions on the mechanism of breathing during hybernation.

Passing allusion by diagrams to the branchial organs of inferior mollusca, conchifera, &c.

Illustrations of new dissections of the breathing organs of the Annelida found on the coast of Swansea; preparations and microscope.

Preparations illustrating the ultimate structure of the gills in crustacea.

Specimens showing the reproduction of Arenicolæ, and their mode of respiring.

On the Physical Conditions regulating the vertical Distribution of Animals in the Atmosphere and the Sea. By THOMAS WILLIAMS, *M.D.*

The subject was treated under the following heads:

Pressure in the Atmosphere; Rarefaction.—Experiment I. Illustrating the influence of density and rarefaction of the atmosphere on birds, affording striking proofs of the penetration and diffusion of air through all parts of the body in birds; newts, frogs and mice included in the experiment for the purposes of contrast.

Pressure in Water, and removal of.—Experiment II. Of removing atmospheric pressure from water containing fishes and Actinia, demonstrating the mechanical functions of the air-bladder, &c.—reflections on the distribution of fishes in the sea.

Experiment III. Of increasing the pressure of the atmosphere over water containing fishes, &c.—curious results of sinking to the bottom, &c.

Experiment IV. Of increasing pressure hydrostatically—effects on fishes, Actinia, &c. &c.

Distribution of Light through Water.—Experiment illustrating the depth to which light will travel through water—influence of, on distribution in depth of plants, zoophytes, &c.

Air of Water.—Experiment proving its condensation at great depths, and its unavailableness for respiration in the deep regions of the sea.

Explains the uniform warmth of the water of the deep sea, as discovered by Sir J. Ross.

Conclusion.—Allusion to the observations of Forbes on the distribution of animals in zones of depth, &c.—doubts raised by experiment with respect to the statements of Sir J. Ross, that the deepest regions of the sea are tenanted by animals and plants, &c.

Additions to the British Flora, and an exhibition of Drawings prepared for publication in the Supplement to English Botany. By C. C. Babington, *M.A., F.L.S.*

The author made a few remarks upon the causes of the recent great increase in the number of recorded British plants, which he supposed had resulted chiefly from the more careful and minute study of plants ensuing upon the attention of our younger botanists being turned to the works of foreign, more especially German and Swedish authors. He then noticed the necessity of attending to minute subdivision of species before any correct determination of what constitutes a species could be obtained, after which doubtless many of the so-called species would be combined into real species. At present no good distinction of species and varieties is known.

Species and varieties noticed:—

Lolium linicola.	Orobanche Picridis.	Filago spathulata.
Apera interrupta.	Malva verticillata.	F. apiculata.
Anacharis Alsinastrum.	Trifolium Molinerii.	Crepis setosa,
Simethis bicolor.	T. strictum.	and some others.
Ranunculus tripartitus.	Melilotus arvensis.	

Periodical Birds observed in the Years 1847 *and* 1848 *near Llanrwst. By* John Blackwall, *F.L.S.*

On the parasitic Character of Rhinanthus crista-galli. *By* Joshua Clarke.

Recent researches have discovered an interesting fact, that a whole group of plants closely allied to the Rhinanthus, is parasitic; but the reason for thus noticing this habit in *R. crista-galli*, is its bearing on the practice of agriculture, viz. the injury and sometimes the destruction of the barley crops on clay lands. The extent of the evil due to this weed having been mentioned, the author stated the mode of effecting the injury as follows:—The fibres of the root of the Rhinanthus attach themselves to the fibres of the barley on which they grow. They then form small, round tubers, or what perhaps might be more properly called *spongioles*, on the sides of the fibres, which embrace the fibres so effectually, that they suck the juices of the plant so as to starve it, and sometimes ultimately destroy it.

Note on the Development of Pollen. By A. Henfrey, *F.L.S.*

The object of this note was to offer evidence from original investigation that the parent-cells of the pollen-cells are not formed through the agency of cytoblasts.

The polliniferous tissue of the anther in *Tradescantia* at first exhibits a continuous cellular structure; in the cells composing this new cells are formed around the entire periphery of the protoplasm, completely filling the original cells, the walls of which then decay leaving the new cells (the parent-cells of the pollen) free. The protoplasm of the parent-cells divides into two and then into four portions, so that two septa, generally crossing at right angles, are found, dividing the original cavity into four cells (the special parent-cells), each generally having the form of a quarter of a sphere. The protoplasm of these again forms a layer around its whole periphery, whereby a new cell (the pollen-cell) originates in each cavity. The walls of the parent and special parent-cells then decay leaving the pollen-cells free. The nuclei never make their appearance before the formation of the septa in the parent-cells.

On some Vegetable Monstrosities illustrating the Laws of Morphology. By E. LANKESTER, *M.D., F.R.S.*

The author stated that the only way of arriving at a proper knowledge of the import and relation of the organs of plants, was to study the history of the development of each organ from its primitive cells; by this means those laws of morphology had been evolved which were so successfully applied to systematic botany at the present day. Although morphology must principally rest on observation, more especially with the aid of the microscope, as experiment could hardly be made in this department of inquiry, yet nature sometimes experimented as it were for us, and by arresting organs in their process of development, presented to us in a permanent form, the various transitionary stages of a normal development. Plants, or parts of plants presenting these forms, were called "monstrous," "monsters," or "monstrosities," terms borrowed from the animal kingdom. These permanent forms of the lower stages of development were found in all parts of the plant, and were worthy of study as confirming or modifying the general laws of morphology. The following instances had recently occurred under the author's observation, and he thought them worthy of record.

In the earliest periods of the history of the development of the leaf its position was alternate, one leaf above the other, subsequently the leaves in many families became opposite or verticillate. An instance was given of the original alternate type remaining in the *Hippuris vulgaris*, in which the leaves, instead of being in whorls, were arranged alternately in a spiral upon the stem.

In the conversion of the leaf-bud into the flower-bud, bracts were the organs which indicated the earliest change in the leaf. Two instances were exhibited, one of *Plantago major*, found by the author, and the other *Plantago media*, presented to him by Dr. Lindley, in whose garden it grew as a permanent variety, in which the bracts normally situated at the base of the flower, and smaller than that organ, retained the character of fully-formed leaves.

The sepals, petals and stamens exhibited still further departures from the ordinary character of the leaf. These however often retained the appearance of the leaf after the tendency to form the flower had commenced. As an instance of this specimens were exhibited of the *Brassica Napa*, in which, in the place of the sepals, petals and stamens, there were developed three rows of succulent leaf-like organs. This had arisen from the attack of a fungus. Reference was also made to specimens of *Trifolium repens*, which had been gathered by the author in company with Professor E. Forbes, Mr. A. Henfrey and Robert Austen, Esq., at Chilworth Manor, in which the parts of the flower exhibited the characters of the leaves, and the short flower-stalks were elongated into the character of the stem.

The highest tendency of the plant was the production of the flower, and where this tendency was greatest we must seek the typical form of the vegetable kingdom. This was found in the *Compositæ*. In this family the tendency to the production of flowers was so strong, that arrests of development were seldom recorded. A specimen of *Tragopogon pratensis* was exhibited in which the pappus was converted into foliate appendages; the corolla was of a green colour, and the style had assumed also a foliaceous character.

The most central organ of the flower, the pistil, was also in its external parts in the earlier stages of its growth identical with the leaf. In the *Trifolium repens* and *Tragopogon pratensis* just mentioned, it retained this form. The origin of the placenta and ovules, within the carpellary leaves, must still be regarded as an undecided point. An instance of the capsule of the *Papaver somniferum* was exhibited, in which, in the interior of the capsule at its base, the growing point, there was present an abnormal growth, consisting of four leaf-like organs, opposite each other, separate above and united at the base, forming a kind of pedicel; each of the leaves was partly united by the margins, forming a kind of cavity which was covered by a curve of the leaf at its apex; one of the leaves was divided into two parts, each containing a cavity; on the edges of the leaves above was a changed condition of the tissue resembling the stigma, thus confirming the theory which regarded the stigma of Papaveraceæ as the result of the union of the two edges of two carpellary leaves. The author regarded this monstrosity as affording evidence against the theory of the development of the placenta and ovules independent of the carpellary leaf.

Another morphological question existed, and that was as to whether an inferior ovary should be regarded as the result of the growth of the carpellary leaf or of the portion of the stem on which it was seated. Some gooseberries were exhibited in which bracts were growing from the surface of the berry, and which might be regarded as indicative rather of the axial than the foliar character of the fruit.

The proximate cause of these abnormal forms seems to be an over-nutrition of the part, which is produced either by culture or the attacks of parasitic fungi or insects. In these cases the formative energy of the plant seemed not able to resist the tendency to produce its tissues in the simplest form, that of the leaf.

On a Peculiarity in the Protococcus nivalis. *By* MATTHEW MOGGRIDGE.

On the 12th of August 1845, near Delvin Head, Gower, at a place where water oozing out of the old red sandstone stagnates upon freshwater mud, I gathered *Protococcus nivalis*, but was prevented from observing it satisfactorily under the microscope.

Since that period I have found it each year on the same spot; and though the same conditions apparently obtain in numerous places in the immediate vicinity, the habitat appears to be confined to one precise spot.

In 1846 I found the *Protococcus nivalis* in pools in the rocky bed of the river Pyrddyn (about 40 miles from the former station), a little above and below the Lady's Fall.

From 1845 to the present time I have made each year many observations (chiefly with the $\frac{1}{4}$ inch) on this plant. The peculiarity to which I would draw attention is the occasional presence and office of a tube, in length sometimes two-thirds the diameter of the globule. This I have myself repeatedly seen, and on one occasion showed it to my excellent friend Dr. Hooker.

Agardt has figured the *Protococcus Grevillii* with a somewhat similar appendage; but he regards it as being a pedicle or means of attachment; and the difference between this species and the *nivalis* has not been apparent to me, as in observations on the same specimens carried on, sometimes for eight weeks, both forms occurred; and I believe the species to be identical, as indeed would appear by Mr. Hassall's book.

In the cases above referred to, the passage of the granules from the globule through the tube appeared very decided; the granular mass in the interior being lessened—the tube containing several granules, and in the instance which I exhibited to Dr. Hooker, one granule being seen near the mouth of the tube, having to all appearance just escaped and being free in the water.

I may add, that on no occasion has any attachment of this tube at its extremity been perceptible to me; and would suggest that this is one—I do not say the only—mode in which the granules escape from the parent cell.

On the Colour Stripes of a Rose (Rosa sempervirens), *single.* *By* JOHN PHILLIPS, *F.R.S., F.G.S.*

After some observations on the colour in the cells of plants, and the distribution of the tints according to structure, the author gave the following statement:—

The large firm petals of this beautiful single rose, when fully expanded and grown in an open aspect, are white, with a delicate tint of yellow toward the base, and, in very bright hot weather, an almost indiscernible blush of red. But there are on the flower two bands of very full clear red, which commonly appear on one petal only, and then generally converge and unite at an obtuse angle at or near the middle of the free edge of the petal. These bands are visible on the outside of the flower only, for the red dye does not penetrate to the interior. This is the usual appearance, but it sometimes happens that, while two colour stripes appear on one petal, and are convergent upon it, they do not meet at a point. When this happens, some portions of red appear on one or more of the other petals of the flower, giving a slightly variegated aspect to the whole. There are cases also of one stripe being on one petal, and the other on parts of two others.

Since it appears clearly from the above examples of variation in the place of the colour stripes, that they are independent of any structural peculiarity of the petals of the flower, it appeared to me that their form and distribution must be dependent on some other circumstance in the organization of the flower or the arrangement of its envelopes. Watching, therefore, the unfolding of the flower from its early bud, I

have found that the colour stripe is not visible in the petals while they are entirely covered by the calyx; but that when the calyx, opening in a slit across the apex of the bud, presents to the light a portion of the petals folded on one another, this portion, and this only, acquires the deep red dye which makes the colour stripe. When, as is often the case, one petal is so folded as to cover or nearly cover all the others, and the opening of the calyx passes over it alone, this petal receives the whole dye; it alone is striped, and the stripes converge to a point; but when the outer petal does not so fully cover the others, and the opening crosses not the surface of that petal only, but also the edges and surfaces of one or more of the others, these edges and surfaces partake of the red stripe, which is really in its origin one continuous band on the bud.

From these facts it may be concluded that the limited red dye of this rose is due to light acting during a very short period of time on whatever cells of the petals may happen to lie in the zone which is uncovered by the calyx and released from its pressure; that there is no peculiar susceptibility for colour in these cells which distinguishes them from the others, all being in fact susceptible of this colour, but only in a particular stage of growth, viz. that which precedes the full opening of the calyx into its five segments.

In a few cases it has happened that one of these rose-buds opening in a very shady situation has received no red dye, but remained altogether white; and by experimentally covering a bud with a black hood, the development of red dye has been entirely prevented. A bud entirely covered with a glass case was very much retarded in flowering, and opened colourless.

I have found, by examining many other roses, single and double, that the same principle, of the colour depending on partial exposure of the petal to light at a particular epoch of growth, is capable of extensive application to white roses whose outer petals are in any degree dyed red; but it seldom happens that in rose petals the susceptibility for a red dye is so remarkably limited as in the example chosen; the dehiscence of the calyx determines indeed in many cases a band or bands of darker tint, but this generally spreads so far to the right and left beneath the leaves of the calyx, as not to catch the attention.

I do not venture at present to offer this explanation of the tints of these roses as a general view applicable to other flowers, in which, frequently, there is a specific determination of colour to specific parts of the floral envelopes; but I think it probable that many striped and spotted flowers may yield to observation and experiment proof that the distribution of their hues is in some degree governed by the manner in which their buds are released from pressure and exposed to light.

On an apparently undescribed state of the Palmelleæ, with a few Observations on Gemmation in the Lower Tribes of Plants. By G. H. K. Thwaites.

The *Palmelleæ* are usually described as consisting of separate cells, imbedded in a gelatine, each cell being supposed to represent a single plant. Mr. C. E. Broome, however, has discovered that in an early stage of *Palmella botryoides* of Greville, the plant consists of a number of branched filaments without septa, containing endochrome, and having their ultimate ramifications terminated by the ordinary cells of the *Palmella*; around each of these cells a quantity of gelatine is developed; they subsequently become detached from the filaments, and develope the mucous prolongations, which, as Mr. Hassall has observed, are probably characteristic of most, if not all the species of this tribe of plants. Mr. Broome's observations have been confirmed by the author in the species above-mentioned, as well as in *Coccochloris rufescens*, Brébisson ?, another species of the *Palmelleæ*. Mr. Thwaites considered that the separation of the cells from the filaments, and the fact of each of the cells then assuming an independent vitality, should be viewed as a gemmation taking place, being rather a division of the individual plant than a reproduction of the species; and therefore the subsequent fissiparous division of these separated cells would be a continuation of the same process of gemmation. The author proceeded to show to what extent gemmation takes place in the lower tribes of plants, instancing the mosses, in which it would appear to commence even in the subdivision of the contents of the sporangium; if the mass of sporules is to be considered, as seems probable, the representative of one embryo in the higher plant, the phytons produced from the con-

fervoid filaments originating from the sporules are another form of gemmation in the mosses; and gemmation also takes place in the perfect state of the plant in *Bryum androgynum* and other species. In the *Lichens* and *Hepaticæ* there is also exhibited a great tendency to produce gemmæ. If the opinion now advanced with reference to gemmation be the correct one, it follows that in some species of mosses, such as *Encalypta streptocarpa*, and of lichens, as *Parmelia physodes*, in which true reproduction by means of spores seems scarcely ever to take place in some localities, an individual plant, by means of its gemmæ or offsets, may attain the age of our largest trees, and occupy as large a space in the economy of nature. The tendency to produce gemmæ in the lower tribes of plants seems to warrant our considering that what has been described by authors as a second form of fructification in some of the Algæ, should be rather referred to gemmation: for example,—the *tetraspores* of the *Florideæ*, the *Opseospermata* of *Draparnaldia* and *Chætophora*, and what has been described by Thuret as the spore of *Vaucheria*. The author took occasion to observe that he did not consider the cilia with which the last-named organ is furnished, as affording any proof of a higher character of organization than if no such cilia existed, and he was inclined to believe that these appendages are merely a modification of cell-membrane, which latter is probably, judging from its mechanical properties, made up of a mass of such delicate filaments as those forming the cilia.

On a supposed connexion between an insufficient Use of Salt in Food and the Progress of Asiatic Cholera. By W. H. Crook, *LL.D.*

In this communication the author surveyed the geographical and social position of the district in which this kind of cholera originates, and inferred that in that district the use of salt, as an article of daily consumption, was (by artificial arrangements) limited to an amount far below that which the healthy and vigorous sustentation of the functions of life requires. He then examined the relation of fatality and prevalence of cholera in different countries of Europe to the price and consumption of salt, and infers as not improbable that a deficient quantity of salt in the food of a nation may predispose many of its inhabitants to receive and generate the virus of cholera, or render them less able to resist its attacks.

An attempt to give a Physiological Explanation how Persons both Blind, Deaf and Dumb from Infancy interpret the Communications of others by their Touch only. By Richard Fowler, *M.D., F.R.S.*

The facility with which young blind and deaf persons acquire such efficiency in their fingers as to enable them to substitute touch for loss of both sight and hearing, admits of a physiological explanation from the following considerations:—

That the knowledge of objects and their various relations is not from the specific nerve of each organ of sense, but from the muscular sense residing in the muscles by which they are adjusted. Mere contact without pressure gives no knowledge of the forms or bulk of objects, and soon ceases to excite any sensation if the muscles which move the fingers are not in action. This fact, that all our distinguishing sensations are in the muscular sense of adjusting muscles, seems to afford a satisfactory proof that it is by this objects appear erect, though in the dead eye they are inverted when seen on the retina. When the head is unmoved and the eye alone raised to look up at the ceiling, we have a contractile feeling in the elevator muscles of the eye and forehead, and when we depress our eyes we have analogous feelings in the depressing muscles. Such muscular sensations, like those of the larynx, pass unheeded by those who can both hear and see, but the slightest sensations indicative of the meaning of others are objects of anxious attention to the blind and deaf, more particularly when new to them. This excitement by novelty of feeling is well marked by Sir H. Davy, who said he felt an extended sense of touch when he had for some time breathed the nitrous oxide gas, and this probably from the larger proportion of oxygen than in atmospheric air. For I think it will be found, that simultaneously with retransmission of motor influence to the adjusting muscles of any

part, there is also retransmission to its arteries to ensure a supply of blood (the source), from which both sensibility and contractibility are sustained.

Captain Ibbetson read a paper which he had translated from the French, on the Chemical and Physiological effects of feeding Fowls, and on the changes and chemical composition of Eggs during incubation, by Dr. Sacc.

The first part of this paper gave an account of the results of feeding a bantam cock and hen on barley alone. At the end of a week it was found that the cock had gained 18 grammes (a gramme is 15¼ grains English) and the hen had lost 21 grammes, but had laid in the mean time an egg weighing 22 grammes; in addition to the barley a certain quantity of carbonate of lime had been consumed. The egg on being examined was found to contain—

Albumen	19·49
Oil	27·84
Water	52·67—100·00

In hens ordinarily fed the egg contained—

Albumen	17
Oil............................	29
Water	54 —100

Thus showing that the barley-fed hen laid eggs with a larger quantity of solid organic matter than ordinarily fed hens.

It was found that hens during incubation lose weight. A hen before incubation weighed 672·155 grammes, after it 483·202 grammes. During incubation eggs lose weight in the following proportion :—

1st week 5 per cent. 2nd week 9 per cent. 3rd week 3 per cent.

osing altogether 17 per cent. of their weight. The shell of the egg was found to weigh 18 per cent. of the egg, and to be composed principally of carbonate of lime. The shell of the egg is not formed unless the animal has access to carbonate of lime in some form or other. The carbonate of lime is deposited on the egg from without, and is carried to the egg in a state of solution in carbonic acid. Phosphate of lime and traces of iron were found in the albumen and the yolk of the egg, and also soda. The function of the albumen or white of the egg appears to be, first, to furnish the young bird with phosphate of lime for its bones and other earthy and alkaline salts; and, secondly, to supply water, the material for the muscles, and to hold in solution the carbonic acid breathed by the young bird before it is hatched. A communication is constantly kept up between the atmosphere and the chick by the shell, which is the organ of the gaseous pulmonary and cutaneous excretions. The yolk of the egg is principally composed of oily matter, which appears to be taken into the system of the young chick, and is used in respiration for the purpose of maintaining animal heat. Thus it is found that in the contents of the new-laid egg there are the same principles surrounding the young chick as there is in the vegetable kingdom for the supply of the whole animal kingdom. We have, first, proteine for nutrition; second, oil for combustion; and, third, various salts for combining with the agents of nutrition.

On the erroneous division of the Cervical and Dorsal Vertebræ, and the connection of the First Rib with the Seventh Vertebra, and the normal position of the Head of the Rib in Mammals. By Dr. MACDONALD, *F.R.S.E., L.S., G.S. &c.*

Cuvier was most successful in the application of organic characters in systematic zoology and palæontology, and from his data almost all our modern zoologists have copied their elementary and systematic treatises.

From a very extended examination of the skeletons of the vertebral classes, Cuvier early adopted and maintained, as an essential character of the whole class of mammals, that they were distinguished by having seven cervical vertebræ as in man. Unfortunately this was based on a hasty adoption of the anthropotomist, who had

restricted his examination to the dried skeleton and the still drier descriptions of human osteology. Had a more scientific course been pursued by the investigation of the neurological distribution, we feel that this error would not have been so extensively adopted, and in fact would not have been proposed by so excellent an observer as Cuvier. Even in the skeleton of man, as best articulated, nine of the twelve ribs have their heads articulated opposite the intervertebral space, being equally connected with each of the adjoining vertebræ. This we assume as the normal position in the mammals, and even in many of the reptiles, and therefore the case of the first, eleventh and twelfth ribs in man are the exceptions.

A vertebra having a rib attached, is considered dorsal in the osteology of mammals. The normal position of the head of the rib in the intervertebral space is beautifully displayed in the disposition of the ligaments, which in a stellate or divergent form unite by three tendons the head of the rib to the intervertebral cartilage and adjoining vertebræ.

In the turtle this arrangement is also very well marked. As twelve ribs require twelve spaces and thirteen bodies to form these spaces, we require thirteen instead of twelve dorsal vertebræ. This will reduce the number of the cervical to six. By a very large induction and examination of the skeletons of recent as well as extinct species of mammals, we are fully satisfied, that with few exceptions, it will be found that there are only six cervical vertebræ in the mammal class, and that this should be adopted as the normal type.

The elephant was the first instance in which we observed the confirmation of what we had previously proposed as the true enumeration of the cervical vertebræ in man, from a consideration of the distribution of the spinal nerves forming the brachial plexus. We subsequently examined the very valuable Museums of the University and College of Surgeons of Edinburgh, and more recently enjoyed the opportunity of examining those of the British Museum, College of Surgeons, and Guy's Hospital; and from these and others of a more limited extent, we found that there were only six cervical vertebræ unconnected with ribs, or rather that the first rib was articulated with the seventh vertebra in the following classes:—Quadrumana, from a very great number; Carnivora, from all but the seals; Rodentia, Pachydermata, Pecora, Cervi, Cetacea; the only exceptions met with were the seals and one skeleton of a kangaroo in Guy's Hospital Museum. In man, the first rib is occasionally in the normal position opposite the intervertebral space; and when we find that the eighth vertebra has an undue share of costal attachment compared with all the rest, we may easily suppose that this has arisen from the primary branchial arch in the reptiloid phase of the fœtus, causing the lowering of the head of the rib, thus at the same time producing greater horizontality in closing in the summit of the thorax, and giving greater freedom for the passage of the subclavian artery and vein over the broad surface, instead of the sharp border or edge. There is another point of view in which this has a bearing; the usually defined exception of the *Bradypus tridactylus* affords grounds for the supposition that the cervical vertebræ are, like those of the cranium, arranged in pairs, for there we have not an additional vertebra, but an additional pair of vertebræ. In a former communication (read at the Cambridge meeting of the Association) we presented a sketch of the arrangement of the cranial vertebræ in pairs as the only mode or principle of unravelling the maze in which they have been so long and even still are involved.

The next subject for correction is that proposed by Prof. Owen, who considers the scapulo-clavicular arch and anterior extremities as the divergent lamina of the occipital bone. Without attempting a full analysis and critical examination of this theory, we may shortly state the following objections:—I. In the mammals this is really composed of at least two laminæ. II. It is neurologically connected in this class with the lower cervical and upper thoracic or humeral region. III. It is also in the same position in birds and in the chelonian reptiles; it is attached anterior to the dorsal vertebræ by the triquetron as a separate bone, and which is only typified by the triquetral or triangular surface of the spine of the scapula over which the trapezius plays, and to which the minor rhomboid is attached. IV. But the most striking objection lies in the case of fishes. The author presented to meetings of the Association at Glasgow and Cambridge, proof that what had been misnamed and mis-

taken for the thoracic or anterior extremity, and called by ichthyologists, judging from external character only, the pectoral fin, was really the coxal segment and leg, and not the humeral arch. The author presented a sketch copied from the Lectures on Comparative Anatomy by Prof. Owen, to show how the mistake had arisen. The object of the diagram was to show that in the human foot, the analogy to the human arm may be traced by merely elongating the calcis and scaphoid bones, so as to represent the ulna and radius, while the astragalus may typify the very compressed humerus; in the fish the foot is turned with the sole or palmar aspect forwards, consequently what is the internal malleolus in man and mammals becomes the external in the fish, and so very much developed, that it forms in the osseous fishes the larger part of the tibia, meeting almost with its fellow from the opposite arch under the mesobranchial or hyoid region, and called by Cuvier the scapulo-claviculaire, and by Owen the coracoid, having the fibula more internal and called epicoracoid by Owen.

Should the Section agree to this view of the pectoral being the coxal instead of the scapular or respiratory extremity, they will perceive that it cannot be the divergent lamina of the occipital bone. It would require too long a notice, and also a demonstration of specimens, to render this subject fully evident; but the author is anxious to contribute, by a prompt correction of what he deems error, data to secure the fundamental basis of this important branch of anatomical study.

On the Homologies and Notation of the Dental System in Mammalia. *By* Professor Owen, *M.D., F.R.S.*

The Professor commenced by observing that one of the results of the determination of the homologies of parts of the animal body was the power of denoting them by symbols, and gave, in illustration of the advantages of this substitute for verbal definitions, some descriptions of the order of development and change of dentition in different mammalia, and especially in the genus *Macropus*, Shaw. He had shown that the formula which had been supposed by Cuvier to distinguish the small kangaroos (*Halmaturus*) from the *Macropus* of Cuvier, was the same essentially in both genera, the differences depending only on the length of time during which certain teeth were retained. The true formula of the *Macropodidæ* was—

$$i\,\frac{3-3}{1-1},\ c\,\frac{0-0}{0-0},\ p\,\frac{1-1}{1-1},\ m\,\frac{4-4}{4-4}=28.$$

The canines are never functionally developed, though minute germs occur in the upper jaw of some of the smaller species, and in the embryo state of all kangaroos. The author had not described the changes of the teeth or given the deciduous formula of the kangaroos in his 'Odontography,' nor had any additional information been given in later works. Mr. Waterhouse, in his 'Natural History of Mammalia,' had confirmed the author's determination of the permanent formula of the dentition of the *Macropodidæ*, and had abandoned the Cuvierian one.

The deciduous dentition of *Macropus Major* was $i\,\frac{3-3}{1-1},\ c\,\frac{1-1}{0-0},\ m\,\frac{2-2}{2-2}=18.$ When the young kangaroo quits the pouch, the *dii* (milk-incisors) and *dcc* (milk-canines) are shed, and the dentition is $i\,\frac{1-1}{1-1},\ m\,\frac{2-2}{2-2}=12.$ The incisors were *i* 1 (first permanent incisors); the molars were *d* 3 and *d* 4 (the milk-molars homologous with those so numbered in the typical dentition of the horse, hog). The next stage in the kangaroo is the acquisition of *i* 2 in the upper jaw (second permanent incisor), and of *m* 1 (first permanent true molar) in both jaws, formulised by—

$$i\,\frac{2-2}{1-1},\ dm\,\frac{2-2}{2-2},\ m\,\frac{1-1}{1-1}=18.$$

At one year old the dentition was $i\,\frac{3-3}{1-1},\ dm\,\frac{2-2}{2-2},\ m\,\frac{2=2}{2-2}=24.$ The next stage is the shedding of *d* 3 and the appearance in place of *m* 3. Then *d* 4 is shed and succeeded by *p* 4,—the single premolar which displaces *d* 4 vertically. Finally,

m 4—the last true molar—comes into place, and in *Macropus gigas* the premolar is simultaneously shed.

Thus four individuals of the great kangaroo may be found to have the same numerical molar series, viz. $m\frac{4-4}{4-4}$, and yet not any of them have the same or homologous teeth. The four grinders, for example, may be—

d 3, *d* 4, *m* 1, *m* 2; or
d 4, *m* 1, *m* 2, *m* 3; or
p 1, *m* 1, *m* 2, *m* 3; or
m 1, *m* 2, *m* 3, *m* 4.

Prof. Owen, not having traced out when he published his 'Odontography' all this complex interchange and alternating sequence of the dentition of the kangaroo, had been compelled to postpone any definition of the deciduous formula until all the stages had been observed. The order described was not that followed in some of the smaller kangaroos. In *Macropus Bonettii*, *e. g.* the acquisition of *m* 3 is not accompanied by the shedding of *d* 3: a skull of that species 5 in. in length, had $m\frac{5-5}{5-5}$, being *d* 3, *d* 4, *m* 1, *m* 2, and *m* 3: both milk molars are shed and replaced by the single premolar *p* 4, but this tooth is not pushed out by the rising into place of the last molar, *m* 4: hence the mature dentition shows five grinders on each side, or $p\frac{1-1}{1-1}$, $m\frac{4-4}{4-4}$. Thus the total number of molar teeth developed in the kangaroos is 28, consisting of 2 deciduous molars, 1 premolar and 4 permanent molars on each side of both jaws. The deciduous molars were the homologues of those in the human subject, viz. *d m* 3 and 4; the premolar is the homologue of the second bicuspid, or *p* 4; the three anterior molars answer to the three true or tuberculate molars in man, viz. *m* 1, 2 and 3: the fourth molar in the kangaroo is a supernumerary tooth.

After describing other particulars in which the proposed notation for the individual teeth was exemplified, Prof. Owen proceeded to observe, that the substitution of signs for verbal descriptions was at once the power of the algebraist and the proof of the exactness of mathematical reasoning. To gain the like power for anatomical science should be the chief aim of its cultivators; to this end the determination of the homologies of parts was the indispensable step which should be followed by denoting the part by a symbol representing it under all its modifications of form and in all the species of animals in which such part existed.

As an example of the amount of information which might thereby be conveyed in a small compass, several illustrations were given, amongst which were the following:—The permanent dentition of the *Anoplotherium* was—

$$i\frac{3-3}{3-3},\ c\frac{1-1}{1-1},\ p\frac{4-4}{4-4},\ m\frac{3-3}{3-3}=44.$$

This was stated to be an example of the typical series of teeth in the placental mammalia with true premolars. The deciduous dentition of the *Anoplotherium* was—

$i\frac{3-3}{3-3}$, $c\frac{1-1}{1-1}$, $dm\frac{4-4}{4-4}=32$: *d m* 1 was succeeded by *p* 1, *d m* 2 by *p* 2, *d m* 3 by *p* 3, *d m* 4 by *p* 4: but *m* 1 was in place before *d m* 1 was shed; *m* 2 was coincident with *p* 1 and *p* 2; next came *m* 3 and *p* 3; and then, coincidently, *p* 4 and *m* 3.

The permanent dentition of the horse was $i\frac{3-3}{3-3}$, $c\frac{1-1}{1-1}$, $p\frac{3-3}{3-3}$, $m\frac{3-3}{3-3}=40$: its deciduous dentition is $i\frac{3-3}{3-3}$, $c\frac{1-1}{1-1}$, $dm\frac{4-4}{4-4}=32$: *d m* 1 is not succeeded by *p* 1; the other three *d m m* are succeeded by teeth which answer to *p* 2, *p* 3 and *p* 4 of the *Anoplotherium*.

In the dog, on the other hand, there are $p\frac{4-4}{4-4}$; but only $dm\frac{3-3}{3-3}$: *p* 1 is not

preceded by a calcified *dm* 1, and the *dm m* (deciduous molars) in use answer to *dm* 2, *dm* 3 and *dm* 4 in the horse and *Anoplotherium*. The permanent molars of the dog are $\frac{2-2}{3-3}$, answering to *m* 1 and *m* 2 in the upper jaw, and to *m* 1, *m* 2 and *m* 3, in the lower jaw of the horse. With regard to the human subject, of which the deciduous and permanent teeth were formulised in the author's 'Odontography,' the first *d m* answers to *d m* 3 in the dog, horse, &c., and is succeeded in the eighth year by a *p m*, answering to *p* 3, and *d m* 4 is succeeded by *p* 4, before the completion of the tenth year: *m* 1 usually makes its appearance in the sixth year; *m* 2 between the twelfth and fourteenth years; *m* 3 at or after the eighteenth year, whence it is called the 'wisdom-tooth.'

Now the description of the foregoing anatomical facts by the ordinary language and verbal definitions of the teeth would occupy about five pages of type used in 'Bell's Anatomy,' and one disadvantage attending such tax upon the efforts of the attention and memory was to enfeeble the judgement in forming its conclusions, and to impair the power of seizing and appreciating the results of the comparisons.

Prof. Owen concluded by stating his conviction that nothing would influence more the rapid and successful progress of the knowledge of the structure of animal bodies than the determination of the nature of the parts by tracing their homologies, and the condensation of the propositions respecting them, by attaching to the parts so determined of symbols, or at least single substantive names, distinctly defined. The bones might be denoted by simple numerals, as was proposed in his work on the 'Archetype of the Skeleton.' And the effect of the few symbols for the teeth, which, when explained, were so easily remembered, had been shown to be to render unnecessary the endless repetition of the verbal definitions of the parts, to harmonize conflicting synonyms, to serve as an universal language, and to convey the writer's meaning in the fewest and clearest terms. The entomologist had already partially applied this principle with much success, and the signs ♂ and ♀ for male and female constantly occurred: the astronomer had early availed himself of it in the signs ☉ and ☽ for the sun and moon, and in the different symbols of the planets, &c.; the chemist was greatly advantaged by his extensive system of symbolical notation; and Mr. Babbage had ably advocated the use of this powerful instrument of discovery in geometrical science, in his paper 'On the Influence of Signs in Mathematical Reasoning.'

On the Value of the Origins of Nerves as a Homological Character. By Prof. Owen, *M.D., F.R.S.*

He stated that he was led to offer a few remarks on this subject from the circumstance that the supply of nerves to the arms of man from the lower cervical pairs, and not from cranial nerves, had formed a difficulty to some in accepting his determination of the general homology of the arms as 'diverging appendages of the costal arch of the occipital vertebra.' Since the determination of a general homology was dependent on that of the special homology of parts, it was requisite to inquire how far the preliminary and minor conclusions were affected by that condition of the nerves which had been supposed to invalidate the major proposition cited.

The author assumed that it would be granted that the arms of man were homologous with the fore-limbs of beasts, the wings of birds, and the pectorals of fishes. But in the wing of the fowl the nerves were derived from the thirteenth and fourteenth pairs counting backwards from the brain, whilst the homologous limb in man received nerves from the fifth to the eighth pairs. Taking a closer instance of special homology, Prof. Owen showed that the wings of the swan derived their nerves from very different pairs from those that supplied the wings of the swift; and he presumed that a still greater difference in their relations to the neural axis must have characterized the nerves of the pectoral paddles in the Ichthyosaur and Plesiosaur respectively. The difference in the origins of the nerves of homologous parts was also manifested in the ventral fins of fishes, which present such great varieties of relative position to the head as to afford the ichthyologist his characters of the orders *Abdominales*, *Thoracici*, *Jugulares*.

Now, if these differences in the place of origin of nerves do not invalidate the con-

clusions of special homology, the author contended that they were equally inconclusive against the determination of general homologies. He briefly stated the facts confirmatory of the ideas of Aristotle and Cuvier as to the special homology of the arms of man with the pectoral fins of fish, and summed up the arguments that had been given in his work on the 'Homologies of the Skeleton,' in favour of viewing the attachment of the scapular arch to the occiput in fishes, as the normal one, in relation to the archetype, and as proving that arch to be the hæmal one of the occipital vertebra, and the pectoral fins to be the radiated appendages of such hæmal arch.

ETHNOLOGY.

On the Geographical Distribution of the Languages of Abessinia and the Neighbouring Countries. By Dr. Beke*.

Dr. Beke exhibited a map showing the geographical limits of the various languages spoken in Abessinia and the adjoining countries, in conformity with the classification suggested in the Report on the Languages of Africa, made last year to the British Association by Dr. R. G. Latham. The map comprised Classes 14 to 23 inclusive of that Report.

In his remarks in explanation of this map, the author agreed with Dr. R. G. Latham on all material points, except only as regards the aboriginal languages of Abessinia, which Dr. Beke considers to consist of those not of the Ethiopic but of the Agau class.

The author next proceeded to analyse a list of languages mentioned in the 'Athenæum' of the 12th of April 1845 (No. 911), of which M. d'Abbadie reports that he has collected vocabularies; and he showed that, apparently, they may all be ranged in one or other of Dr. R. G. Latham's classes, which may consequently be regarded as exhaustive of the languages spoken in Abessinia and the countries immediately adjacent.

Dr. Beke also explained the probable origin of the fabulous stories which have been related respecting the Dokos, an alleged nation of pygmies dwelling in the south of Kaffa, but who appear to be a race of savage black people, of little less than the ordinary stature of mankind.

On the Ante-Columbian Discovery of America. By Professor Elton, *D.D.*

The Sagas of Erik the Red, and Thorfin Karlsefne, published by the Royal Society of Northern Antiquaries in 1837, contain the history of the first discovery of America, A.D. 986–1013. The manuscripts published in the 'Antiquitates Americanæ,' give an account also of voyages made by the Scandinavians during the twelfth, thirteenth and fourteenth centuries. They explored a great extent of the eastern coast of North America, fought and traded with the natives, and attempted to establish colonies. The most northern region they called *Hellialand*, i. e. Slateland; the country further south, *Markland*, i. e. Woodland; and the tract still further to the south, *Vinland*, i. e. Vineland. The general features of the country accord with the description given.

This discovery is confirmed by an inscription rock on the Taunton River, at Dighton, Massachussets, found there on the arrival of the first New England colonists, which contains the word Thorfinus, and 132. One of the Sagas states that Thorfinus, an Icelandic chief, with 132 men, made a voyage to *Vinland* in 1000, remained there three years, and was finally killed in a battle.

In support of the claims of the Welsh to the discovery of America, we have the following information. It is mentioned by three of their bards, Meredyth ap Rhys, Gutwyn Owen, and Cynfrig ap Gronw, all of whom wrote before the discovery by Columbus, that Madoc sailed from Wales in 1170, and after pursuing a westward

* Printed *in extenso* in the Edinburgh New Philosophical Magazine, vol. xlvii. No. 93, for July 1849.

course for some weeks, arrived on a continent where the inhabitants differed from Europeans. He returned to Wales, and subsequently equipped a fleet of ten vessels, and sailed for the same continent; but of that expedition no tidings were ever received. All the information we have on this point at present must be deemed only probable conjecture.

On a quantity of Human Bones discovered in a Field near Billingham, in the County of Durham. By John Hogg, *M.A., F.R.S., F.L.S.*

The author exhibited several human bones, selected from many which were dug up this spring in an arable field, situate about half a mile to the west of Billingham, in the county of Durham. These bones consisted of supra-occipital and parietal bones of the skull, a humerus, portions of the upper and lower jaws with the teeth, &c.: they were in excellent preservation, though some were more decayed than others. The teeth being worn down in a remarkable manner, led to the belief that they were those of a very early and primitive race, which had chiefly fed on hard substances, such as parched pulse, nuts, acorns*, and the like. They were dug up at a trifling depth with a common spade.

For many years past a vast number of human bones have been ploughed up; so much so that women whilst weeding in that field have collected them, and sold them at the neighbouring water-mill, where machinery is used for crushing bones for manure. The field is called *Nutton*, or *Newton Heads*, which has probably been so named from the skulls or *heads* of men having been at times discovered in it. There was nothing whatever to show that these remains had been interred in coffins, or after any regular plan of sepulture; nor is there the least likelihood of the spot having formerly been a burial-place belonging to any church or convent.

In the year 1804, a skull and several human bones were turned up when draining in a grass-field near the same mill; and about the year 1830, in an adjoining grass-field, three skeletons of men were found while some workmen were excavating a part of the field for a line of railway; they however rapidly crumbled to dust on exposure to the air.

Mr. J. Hogg, in endeavouring to account for the appearance of these remains in the fields respectively pointed out, attributed their interment in those spots to one of the following causes, which several local histories have handed down to us:—

First. Hutchinson, in his 'History of Durham,' vol. iii. p. 106, says, "Billingham is memorable for a great battle fought there by Ardulf, king of Northumberland;" and the same is related by a later author† more fully thus: "a civil war broke out in the kingdom of Northumberland, when the mal-contents assassinated Ethelred the king at Corbridge, A.D. 795. Wada was chief of the conspirators, and was attacked by Ardulf, who after a short interval had succeeded Ethelred (about A.D. 800), and a pitched battle was fought near Billingham, which is represented to have been attended with a very great slaughter."

Second. In one of the irruptions of the Danes, about A.D. 910, a king called Reingwald landed a great force (according to Symeon Dunelmensis, lib. 2. cap. 16) on the coast of Northumberland, and expelled or murdered several of the principal inhabitants; and one of his generals, called Scula, laid waste the country from Eden Dene to Billingham‡.

Third. In the tenth century, between A.D. 920–25, Edward the Elder reduced the Danes throughout Northumbria.

The great quantity of human bones however that have been brought to light within the last few years in the before-mentioned arable field, renders the first of these causes the most probable. Yet some persons might perhaps be induced to assign their appearance in all those places, either to some battle consequent upon a later incursion of the Danes or other hostile nation, or to a more recent fight between the natives of that district and some marauding party of freebooters, although of any such having actually occurred nothing whatever is known.

* Many suppose that the *common acorn* could not be eaten on account of its great bitterness; but it is probable that there was some method adopted by the earlier inhabitants to extract it. For a mode still used by the Sardinian peasantry, see Tyndale's Island of Sardinia, vol. iii. p. 191.

† Brewster, Hist. Stockton, edit. 2, p. 10.

‡ See Brewster, Hist. Stock. p. 11, and Surtees, Hist. of Durham, vol. iii. p. 144.

The author then, in the absence of all further historical or traditional accounts, is inclined to refer the interments of the numerous human bones in the fields previously described to the period immediately after the great battle which was fought near Billingham between king Ardulf and the conspirator Wada.

The subsoil of the arable field being very dry, and nearly a pure sand, would preserve those remains for a great many centuries.

The supra-occipital and parietal bones of the skull did not present any physiological peculiarity of structure.

Amongst the collection were an astragalus of a small ox, and a transverse process of a lumbar vertebra, most likely of a horse.

Measurements of a Skull considered to be Burgundian. By Professor RETZIUS.

Diameter.	Metres.
Fronto-occipital	0·188
Frontal	0·098
Occipito-vertical	0·148
Inter-mastoid	0·128
Inter-zygomatic	0·125
Inter-orbital	0·025

General character Germanic.

Notes on a Kirgis Skull. By Professor RETZIUS.

Although belonging to the Turkish tribes, the Kirgis skull departs from the type of the Turk, Cossack and Mongol skulls in being less round, and short, and more developed in its occipito-frontal diameter.

Remarks to accompany a Comparative Vocabulary of eighteen Languages and Dialects of Indian Tribes inhabiting Guiana. By Sir ROBERT H. SCHOMBURGK, *Ph.D.*

These vocabularies were collected by the author during the expeditions which he undertook into the interior of Guiana, namely in the years 1835 to 1839, under the direction of the Geographical Society of London, and in the years 1840 to 1844 as Her Majesty's Commissioner for surveying the boundaries of British Guiana. The territory, which extends from the shores of the Atlantic between the river Corentyn (lat. 6° N., long. 57° W.) to the east, and the Orinoco (lat. 8° 40′ N., long. 60° 30′ W.) to the west, as far southward as the Rio Negro (lat. 1° 30′ S.), and from the banks of the Upper Corentyn (long. 56° 40′ W.) westward to the Cassiquiare (long. 67° 40′ W.), that remarkable natural canal which connects the Orinoco with the Rio Negro, has been more or less explored during the eight years which were dedicated to these expeditions.

The number of vocabularies which he collected during his voyages amounts to eighteen, none of which, as he observes, bear a closer affinity to each other than the French and Italian. Without binding himself strictly to the following division, which he considered merely provisional, he divided these vocabularies into six sections, namely,—

I. *Caribi-Tamanakan.*—1. Caribisi. 2. Accawai. § Waika. 3. Macusi. § Zapara. 4. Arecuna. § Soerikong. 5. Waiyamara. 6. Guinau. 7. Maiongkong. 8. Woyawai. 9. Mawakwa, or Maopityan. 10. Pianoghotto. § Zaramata. §§ Drio. 11. Tiverighotto.

II. *Wapisian-Parauana.*—1. Wapisiana. 2. Atorai. § Taurai, or Dauri. §§ Amaripa. 3. Parauana.

III. *Taruman.*—Taruma.

IV. *Warauan.*—Warau, or Guarauno.

V. *Arawakan.*—Arawaak, or Aruaca.

VI. *Lingua Geral* (dos Rios Negro e Branco).

The subsequent remarks described the regions which are inhabited by the tribes above enumerated, accompanied by some incidental observations respecting their customs and manners, and were followed by a comparative vocabulary of a few words from each, which are added herewith, as the greater number are new to our knowledge of philological ethnography.

Comparative Vocabulary of Guianian Languages and Dialects.

Name of the Tribe.	Sun.	Moon.	Stars.	Earth.	Fire.	Water.	Head (my).	Eyes (my).	Nose (my).
I. Caribi-Tamanakan.									
1. *Caribisi*	Wehu	Nuno	Siriko	Yuporo	Watto	Tuna	Yubupo	Yenuru	Yenetari
2. *Accawai*	Wiyeyu	Nuno	Irema	Ito	Watu	Tuna	Yupopo	Yenuru	Yenotarri
3. *Macusi*	Weh	Kapoi	Siriko	Nung	Apo	Tuna	Pupei	Uyenu	Uyeuna
4. *Arecuna*	Wae	Kapui	Serrika	Nunk	Apok	Tuna	Opuwei, or opei	Yenuru	Uyeuna
§ *Soerigong*	......	......	......	......	......	......	Ipei	Itaäna	Akone
5. *Waiyamara*	Weyu	Nuna	Serrika	Nono	Wato	Tuna	Ipawa	Yenuru	Yonari
6. *Guianau*	Kamuhu	Kewari	Yuwinti	Kati	Tsheke	Oni	Intshebu	Nawisi	Intshe
7. *Maiongkong*	Tshi	Nuna	Yetika	Nono	Wato	Tuna	Hohuha	Uyenuru	Yoanari
8. *Woyawai*	Kamu	Nuni	Serego	Roön	Wetta	Kuishamina	Ighteburi	Eoru	Younari
9. *Mawakwa*	Kamu	Kirsu	Wishi	Tshimari	Tshikasi	Wune	Unkaua	Ngnoso	Ngndewa
10. *Pianoghotto*	Weh	Nuna	Siriko	......	Matto	Tuna	......	Yenei	Yoanari
11. *Tiverighotto*	Weh	Niano	Serika	......	Apoto	Tuna	Oputpa	Oneana	......
II. Wapityan-Paracana.									
1. *Wapityan* or *Wapisiana*	Kamo	Keiirrh	Weri	Emu	Tegherre	Tuna	Unruai-aitana	Ungwawhen	Ungwiitippa
2. *Atoria*	Kamoi	Keiirhe	Watsieirhe	Tari	Tegherre	Tuna	Unruai-eterna	Wawanumte	Ohipe
§ *Tauria*, or *Dauri*	Tamoi	Kaiira	Wonari	Dari	Tekeri	Unnabo	Wauünbarra	Wauüni	Ohebe
III. Taruman.						Onabo			
Taruma	Ouang	Piwa	Wingra	Toto	Hua	Tza	Atta	Atzi	Assa
IV. Warauan.									
Warau	Yah	Wanehu	Kiora	Hota	Icko	Ho	Makwa	Mamu	Mehekadi
V. Arawakan.									
Arawaak	Hadalli	Katsi	Wiwa	Ororu	Hikkihi	Wuniabbo	Dashi	Dakusi	Dasiri
VI. Lingua geral	Yuarassu	Yassu	Yasitata-miri	Ekuin	Yata	......	Akanga	Sissa	Yutin

Remarks.—Orthography adopted in the above vocabularies:—The sound of the vowels is that of the Italian language; *ai*, *ei* is diphthongal, and resembles the sound of *i* in mile; *au* resembles the English *ow* in *how*. The consonants have the usual sound; *c*, *q*, *x* are, however, rejected, and represented by *k*, *kw*, *ks*; *g* is always hard, as in *gate*; *j* is always soft, as in *join*; *s* always as in *house*; *h* distinct, as in *grass-hopper*; *ng* is always nasal; *ph*, *th* are represented by *f*, *th*, and their occurrence is noted in the general remarks.

Comparative Vocabulary, &c.—(*continued.*)

Name of the Tribe.	Mouth (my).	Hand (my).	Foot (my).	Bow.	Arrow.	Dog.	One.	Two.	Three.
I. CARIBI-TAMANAKAN									
1. *Caribisi*	......	Yennari	Pupu (foot)	Hurapa	Purrewa	Keikutshi, or Pero	Owe	Oco	Orwa
2. *Accawai*	Yubotarri	Yenarru	Yubobu	Ureba	Pulewa	Piro	Tigina	Asakre	Osorwo
3. *Macusi*	Hunta	Huyenya	Hupu	Hurapa	Purau	Arimaragha	Tiwing	Sakene	Eserewa
	Mutta (mouth)			Huyuiupai (my)					
4. *Arecuna*	Undack	Uyena	Uta	Urapa	Purrau	Arimaragha	Tauking	Atsakane	Itseberauwani
§ *Soerikong*	......	Ona miara	Itua						
5. *Waiyamara*	Tshuaduru	Yanaroru	Kiporu	Urahaberagha	Parau	Okheri	Tuwine	Assare	Ware
6. *Guinau*	Noma	Inkabo	Intshibe	Tshimari-tshebi	Tshimari	Kwashi	Pareita	Yamike	Piampatyam
7. *Maiongkong*	Undati	Yamutti	Ohutu	Tsimare-huru	Tsimarei	Tsefeti	Toni	Ake	Airtuaba
8. *Woyawai*	Emdari	Yamore	Horori	Klaffa	Woiyu	Tsawari	Tioni	Asaki	Soroau
9. *Mawakwa*	Ngnomiti	Ngnkowa	Ungeopa	Thseÿe	Kengye	......	Apaura	Woaraka	Tamarsi
10. *Pianoghotto*	Yefiri	Yenari	Putu	Urapa	Purau	Keikue			
11. *Tiverighotto*	Opota	......	Upti						
II. WAPITYAN-PARAUANA.									
1. *Wapityan*, or *Wapisiana*	Untaghu	Ungwaipanna	Unketewi	Sumara	Urreghuri	Arimaragha	Peiteieppa	Tiattang	Itikineita
2. *Atorai*	Otaghu	Unkuai	Unkheti	Parauri	Peiïri	Teni	Peitaghpa	Pauiteitegh	Ihikeitaub
§ *Taurai*, or *Daurai*	Otagho	Okei	Okheti	Parauri	Werakure	Teni	Weitappa	Peitategh	Hikeitaba
III. TARUMAN. *Taruma*	Merukukanna	Ahu	Appa	Tzeika	Kupa	Hi	Oshe	Tyuwa	Ungkeha
IV. WARAUAN. *Warau*	Maraho	Mamuhu	Mumo	Hattaboro	Hattabo	Peroro	Hisaka	Monamu	Dianamu
V. ARAWAKAN *Arawaak*	Daliroko	Decabbu	Daweti	Semara-hapa	Semarra	Pero	Abaru	Biama	Kabuin
VI. LINGUA GERAL	Yoro	Ipo	Ipiku	......	......	Yauüra			

The result of the comparison of the languages and dialects of Guiana with those of the American continent in general—namely from Baffin's Bay and Behring's Strait to Patagonia—proves, according to the author, an affinity throughout. The above comparative vocabulary, which consists merely of eighteen words, have afforded him 82 cases for comparison with 102 different languages and dialects of the New World. These comparisons, he says, are not forced by a mere resemblance of a single syllable, but are obvious; and hence the opinion shared by many ethnographers, that there is a general affinity between the races who now inhabit the American continent, has received a new proof through these Guianian languages and dialects.

However, the Guianians are in language more closely allied to the North American tribes of the present day than to the Peruvians and Mexicans. "Let us take," he continues, "for example the word 'dog,' which offers an affinity in five Guianian dialects to Esquimaux, Kliketat (on the north-west coast), Ottawa, Cherokee, Onondago, Seneca, &c., and *not one instance* of resemblance to a South American dialect beyond the province of Guiana, as far as I have had opportunity to compare these dialects."

The author concludes with the following words:—

"The Caribi-Tamanakan section of my Guianian languages is decidedly closer related to the North-American tongues than the other sections, and this circumstance greatly confirms me in the opinion, that we have to look to Florida, Texas, and the eastern foot of the Rocky Mountains, for the origin of the Caribi-Tamanakan races. I consider the Tamanaks, including the Macusis, Arecunas, Pianoghottos, &c. the continental Caribs of South America, and those races which are now known as Caribisis and Accawais, the former inhabitants of the Lower Antilles."

On a Uniform System to reduce Unwritten Languages to Alphabetical Writing in Roman Characters. By Sir ROBERT H. SCHOMBURGK, *Ph.D.*

The author, after remarking that the great evil connected with the confused state of the orthography which has been hitherto adopted for expressing the sound of unwritten languages has been of great disadvantage to the student of philological ethnography, the traveller, and the missionary, observes, that he used for his vocabularies of the Guianian languages and dialects the sound of the Italian vowels and of the English consonants, and rejected all diacritical marks.

He brought under notice that the Church Missionary Society, in connexion with several other missionary institutions then engaged in vernacular translations of unwritten languages, have recently adopted a common system of orthography, which recommends itself for simplicity, and coincides with the method which has already been employed by the translators of African languages, and has likewise been sufficient for expressing the sounds of many languages of the East as well as of Africa.

The system of the Church Missionary Society closely agrees with the one which the author adopted in 1836 for his vocabularies of the Guianian dialects, and is likewise applicable for those who write in the German language. It has already been employed by the great Missionary Institution at Basle, and likewise by others for translating the Scriptures into Susu, Yoruba, Haussa and Tamneh. It is therefore to be hoped that the determination of these institutions to use common rules in reducing unwritten languages, will materially assist to advance that laudable aim of seeing a uniform orthography for unwritten languages introduced among scientific men, travellers and missionaries. "And if the institutions," says the author, "who have taken the lead are only determined to persevere, the circumstance that they constitute not only a powerful party, but the only one at present who have to make a practical application of such a system, will greatly contribute towards its general adoption. Such scientific bodies as the Ethnological Societies of London, Paris, and New York, might accelerate this desirable aim by giving their powerful assistance towards its adoption."

Ethnographical Note on the Vicinity of Charnwood Forest. By JOHN PHILLIPS, *F.R.S., F.G.S.*

While traversing on foot during several months in the early part of the year 1848

a large area of country in the vicinity of Leicester, Nottingham and Derby, the attention of the author was continually arrested by circumstances in the physical character of the population which were very unexpected. If in this district (the district of Danelagh) Danish settlers had replaced or been mixed with a purely Saxon people, the now existing inhabitants should exhibit mainly though not exclusively the blue eye, light hair and ruddy complexion, and commanding stature of the Germanic or Scandinavian races,—as in fact really happens among the mountains of Yorkshire, Cumbria and Northumberland, where these races predominate. But instead of such prevalent signs of Saxon or Danish origin, the author perceived with surprise very frequent examples of black eyes and hair, uniform or rather dark complexion, and contours of countenance which might with more appearance of truth be referred to that branch of the Celtic stem which is represented by the ancient population of South Wales, Cornwall and Armorica. Nor was this circumstance confined to particular classes which might be supposed to have immigrated, but was found to prevail even more positively in the rural populations and most retired situations. It was equally noticed in children of various ages (except infants) and adults; and by repeated estimates the author was confirmed in his impression that in fully half of the rural population in a large area round Charnwood Forest the physical character of the Germanic or Scandinavian people is wanting or complicated with another and very different type, and that only in a smaller part of the population is that character exclusively present.

May we suppose, in explanation of these observations, that a larger proportion of the oppressed Britons was permitted to remain in their ancient midland sites than historians generally admit? Were the Coritanian Britons in this respect peculiarly favoured? Was it a circumstance more observable in the Mercian kingdom than elsewhere? The author, adopting for the present the affirmative on these points, rather than the supposition of these black-eyed races being derived from a blue-eyed ancestry, invited the attention of ethnologists to the curious problem of the actual distribution of aboriginal and immigrated races which the British islands present, a problem very important in history, but of which the solution, whether by philological or physical demonstrations, is becoming every day less and less practicable, through the fusion of dialects and the complication of races.

On the Tumali Language. *By* Dr. L. Tutschek.

The materials for the Tumali language were collected by Dr. Lorenz Tutschek from Dgalo Dgondan Are, one of the four young Africans with whose education he and his late brother had been entrusted by the Duke Maximilian of Bavaria. The locality is one degree south of Obeyhda, in Kordofan. The Tumali area is divided by the mountain-stream Tente into two kingdoms of unequal size—the Tumali-Tokoken and the Tumali-Debili. The first is the smaller, but, at the same time, the seat of government; the *Ellot* of Tumali-Debili being subordinate to the *Ofter* (or *Wofter*) of Tumali-Tokoken, who is again subordinate to the king of Takeli, himself a tributary to the viceroy of Egypt.

The Tumali language is a dialect of the Deier language of Rüppell, or *vice versâ*. It also agrees, to the extent of three-fourths of the words common to the two vocabularies, with the Takeli* of Rüppell.

The details of this language, as communicated *in extenso* by Dr. Tutschek, may be found in the Transactions of the Philological Society for June 23, 1848. Partially, also, they appear in the Report of the present state of African Ethnographical Philology, in the last volume of the Transactions of the British Association.

On the Fazoglo Language. *By* Dr. L. Tutschek.

Collected from a boy born at Hobila, in the south of the Fazoglo country, purchased out of slavery at Alexandria by the Duke Maximilian, and entrusted in the year 1844 to Dr. Tutshek for education.

By referring to a note in the Report of the Transactions of the Sections for last year, it will be seen that the Fazoglo of Tutschek is nearly allied to, if not identical

* See Report of last year, Transactions of the Sections, p. 124.

with, the Qâmamyl of Caillaud. Out of sixty words, compared by Dr. Tutschek, the following coincide:—

English.	Fazoglo.	Qamamyl.
Heart	ago	ago
Wing *	midzê boé	mezébé
Needle	indiri	ndilli
Tree	n'ggolé	engoulé
Rainbow	mässäl	mossol
Ostrich	midzê amuru	minsin merou
Breath	amula	amoula
Balance	mudull	moudulle
Hair	buss	bouss
Belly	io	io
Much	duni	dungue
Beak of bird	midzê andu=*bird's mouth*	missindu
White	hoti	foudy
Black	mili	mili = *blue*
Ass	shilerr	chiler
Ring	dolo	toulou
Goat	mia	mya
Coal	galgashys	kelgui cho
Way	gagal	kagal
Horse	mura	mourha

Further details are to be found in the Transactions of the Philological Society for April 1849.

On the Gael, Breton and Cymry. *By* Archdeacon Williams.

STATISTICS.

Observations on the means of maintaining the Health of Troops in India. *By* Edward Balfour.

After some preliminary remarks, the author stated that intemperance, which had been regarded as a great cause of mortality among the troops in India, would be found to add but a very small proportion to the deaths from climatorial diseases, which were known to continue in spite of the most regular and temperate habits. There seemed to be an unjust impression abroad that a soldier was a very intemperate character; but supposing this to be true, it would be found that other classes of our countrymen did not enjoy a greater immunity from disease. What was the proportion of deaths amongst the highly temperate civilians of India, who were the most intelligent, best clad, best paid, best lodged, and most independent servants of the Indian government? Although the mortality amongst the same class in England from 1801 to 1832 averaged only 9·1 per 1000 annually, according to the accounts of the Equitable Insurance Society, yet Mr. H. T. Prinsep had stated that in the twenty years, from 1809 to 1828 inclusive, the Madras civilians lost 23·8 per 1000 of their strength, the Bengal civilians 25·1 per 1000, and the Bombay civilians 31·7 per 1000. Tables were read to show that the human race enjoy better health in their own than in any foreign country, whatever may be their rank, duties, or comforts.

Contributions to the Statistics of Darlaston. *By* Mr. Kenrick.

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* Quere, *bird's arm.*

Progress and Character of Popular Education in England and Wales, as indicated by the Criminal Returns, 1837-47. *By* JOSEPH FLETCHER, *Hon. Sec. Statistical Society of London.*

The equability between the proportion utterly uninstructed in the commonest arts of scholarship, in and out of gaol, in the kingdom at large, is equally found in many of its provinces, but there is a double deviation from it which indicates a general cause of extensive operation. In the *least* educated districts, the proportion wholly uninstructed among the persons committed for trial is *less* than among the population at large; while in the *most* educated districts, the proportion of the wholly uneducated among the persons committed for trial is proportionally above the average. As this appears, in the southern parts of England, chiefly by comparison between the metropolitan and the midland counties, it might admit of complete explanation by supposing that many of the most ignorant and dissolute of the rural population, finding their way to the metropolis, there entered the latter stages of an unhappy career. But this will not explain the relative excess of the totally ignorant appearing in the criminal calendar of Rutlandshire, the only one of the midland counties remarkably advanced in popular education, nor the coincidence of the like phænomenon with the superior instruction of the East and West Riding of Yorkshire, of Cumberland, of Northumberland and of Durham. Migration of the poor, ignorant and depraved *into* these regions appears to be very improbable; neither is there any conceivable *emigration* of such persons to account for the proportionate defect of the wholly uninstructed in Monmouthshire, South Wales, or Cornwall, or in the whole of the most ignorant and densely populated of the manufacturing counties of Cheshire, Lancashire, the West Riding, Staffordshire, and Worcestershire. In other words, the proportion of the wholly uneducated in gaol is *less* than the proportion of the population at large equally in the *most purely agricultural* districts of the south and east, and in the *most purely mining and manufacturing* districts of the north and west, which are respectively the most *positively* ignorant and criminal; while in the most instructed counties, whether of the north or the south, and whether metropolitan, agricultural, mining, or manufacturing, the converse is seen.

The only explanation of this fact which suggests itself to my mind is, that there is no less difference in the *quality* than in the amount of instruction given in the most and least instructed portions of the kingdom respectively; and that is only a degree of careful uprearing of the young, far higher than that which can be tested by the lowest attainments in reading and writing, that is alone blessed to the good end of righteous living in a Christian hope. It is the abstraction of a greater number of the instructed from the criminal calendars of the better educated districts which there throws the *proportion* of the totally ignorant into excess; and the inferior character of the instruction given in the worse educated districts, which permits a greater number of the instructed to appear before the criminal tribunals, to the reduction of the *relative* proportion of the wholly ignorant comprised in the calendars. Thus regarded, these figures tend greatly to strengthen the impression which I have derived from other sources, that around the moderate amount of really efficient instruction, and really Christian training which prevails even in our best educated districts, there exists a wide margin of spurious schooling, without any good effect either upon the intellect or the heart; and that in the remotest of the agricultural, as of the mining and manufacturing districts, it is this doubtful twilight that generally prevails, with no compensating superiority of vigorous education among the middle and upper classes. Hence it results that the difference in the amount of education, in any rational sense of the term, between one portion of the kingdom and another, is far *greater* than that indicated by the varying proportion which the marriage registers show to be unable to write at all; while as yet we have no test that, for the population at large, will check against the gaol returns of those who can read and write imperfectly, "and read and write well." If we had a test of the latter range of scholarship for each county, in the population at large, it is my conviction that it would furnish far stronger evidence in favour of good education,

than that which we are now permitted to derive merely from a comparison of the numbers wholly uneducated that appear in the marriage registers and in the criminal calendars.

Let us, however, return to the comparative progress of "education," up to the mark of bare reading and writing among the population at large, and those brought up before the criminal tribunals of their country. Here, also, we see a great number of curious coincidences in the contemporaneous increase of marks in the marriage registers, and of the proportion of persons able neither to read nor write in the criminal calendars of the country or district. There are likewise some anomalies, but the general result is a decrease of the proportion wholly uneducated in the criminal calendars at double the rate that it is found to decline in the marriage registers, after reckoning for the difference of the intervals between the data yielding the figures now compared. The decline is scarcely perceptible in the western Celtic districts, and next to them, it is least observable in the great northern and central mining and manufacturing counties, where it has declined only one-thirteenth in five years, while in all the rest of the kingdom it has declined about one-tenth, except in the northern and midland agricultural counties (*contiguous* to the comparatively stationary mining and manufacturing counties), in which it has declined upwards of one-seventh. We thus find the decline of *total* ignorance to be slowest in the most criminal and the most ignorant districts, in which, nevertheless, its decline among those in gaol is greater than in society at large; everywhere indicating the very doubtful quality of a great proportion of that which barely helps its recipients out of the category of the totally ignorant.

The proportion of criminals "reading and writing ill" is seen now to be precisely double that of the criminals "unable to read and write," having increased no less than 5·7 per cent. in the first period of five years, and 0·4 per cent. during a subsequent period of three years, making a total of 6·1 per cent. in the eight years. The class of "superior instruction" being very limited (in fact, in the centesimal proportions, always under a whole figure), and likewise unvarying, this increase must necessarily be derived from only one other of the four classes, besides those who can neither read nor write. From this we have seen that there is a subtraction of 3·1 per cent. in five years, and 1·1 per cent. in three more, making a total of 4·2 per cent. out of the 6·1 per cent. of augmentation observed in the column of "reading and writing ill." The other 1·9 per cent. is derived from the column of "reading and writing well," in which the decline during the first five years was no less than 2·6 per cent., but a retrograde movement during the last three years has reduced this proportion to 1·9.

It is, however, to this heading that I would call especial attention, for this alone affords evidence, both conclusive and satisfactory, of a moral progress. A gradual change in the standard designated "reading and writing well" could alone account for this decline of one-fifth in the proportion of those possessed of this amount of instruction; but I would fain hope that it is a correct indication of a real improvement in the moral tone of the middle classes generally, springing from the source of all truth and all goodness. Even if any portion of it arise from a practical elevation of the standard designated by the heads of each column, this fact will only render still stronger the conclusion already drawn from the increased proportion of those reading and writing ill, which would have been yet greater, but for the retention of some that might have been included in that column in the number of the totally uninstructed.

Summary Table, comparing the different Districts of England and Wales in respect to the Proportion of Persons committed for Trial in each, who show the several Degrees of Instruction described underneath, and to the changes in those Proportions effected in the course of three years, as tested by the averages of 1842, 1843 and 1844, compared with those of 1845, 1846 and 1847.

DISTRICTS.	Neither read nor write. Proportion per cent. of criminals. 1842 to 1844.	Neither read nor write. Proportion per cent. of criminals. 1845 to 1847.	Neither read nor write. Excess or deficiency per cent.	Read or write imperfectly. Proportion per cent. of criminals. 1842 to 1844.	Read or write imperfectly. Proportion per cent. of criminals. 1845 to 1847.	Read or write imperfectly. Excess or deficiency per cent.	Read and write well. Proportion per cent. of criminals. 1842 to 1844.	Read and write well. Proportion per cent. of criminals. 1845 to 1847.	Read and write well. Excess or deficiency per cent.	Superior education. Proportion per cent. of criminals. 1842 to 1844.	Superior education. Proportion per cent. of criminals. 1845 to 1847.	Superior education. Excess or deficiency per cent.	Actual number of committals on the average of the three years. 1842 to 1844.	Actual number of committals on the average of the three years. 1845 to 1847.	Proportion per cent. above and below the average of all England and Wales of those who could neither read nor write, on the average of the three years. 1842 to 1844.	Proportion per cent. above and below the average of all England and Wales of those who could neither read nor write, on the average of the three years. 1845 to 1847.	Per-centage of increase or decrease in the number of committals from 1842 to 1844, and 1845 to 1847.
LEAST INSTRUCTED.																	
II. The south, midland and eastern agricultural counties, exclusive of the metropolitan	34·3	34·2	−0·1	58·7	58·9	+0·2	6·6	6·5	−0·1	0·4	0·4	......	3021·34	2620·00	+ 9·4	+13·2	−13·2
V. The south midland agricultural and manufacturing counties ...	38·6	36·5	−2·1	54·8	53·9	−0·9	6·4	9·4	+3·0	0·2	0·2	......	1610·33	1297·00	+23·3	+20·7	−19·4
VI. The western (Celtic) agricultural and mining counties	33·1	31·5	−1·6	59·3	60·4	+1·1	7·2	7·5	+0·3	0·4	0·6	+0·2	1050·00	934·66	+ 6·0	+ 4·2	−10·9
VIII. The northern and midland manufacturing and mining counties	32·6	30·4	−2·2	59·9	60·8	+0·9	6·9	8·2	+1·3	0·6	0·6	......	9325·34	7190·00	+ 4·4	+ 0·9	−22·9
Total of the least instructed districts	33·6	32·0	−1·6	59·1	59·6	+0·5	6·8	7·9	+1·1	0·5	0·5	......	15007·01	12041·66	+ 7·5	+ 5·9	−19·7
MOST INSTRUCTED.																	
I. The southern agricultural and maritime counties	30·4	32·5	+2·1	61·9	59·7	−2·2	7·3	7·3	......	0·4	0·5	+0·1	2518·33	2417·99	− 2·9	+ 7·7	− 3·9
III. The two metropolitan counties......	22·8	23·6	+0·8	59·1	60·5	+1·4	17·8	15·7	−2·1	0·3	0·2	−0·1	3894·00	4448·00	−27·0	−21·6	+14·2
IV. The north midland and north-eastern agricultural counties ...	33·7	35·0	+1·3	61·2	61·0	−0·2	4·8	3·8	−1·0	0·3	0·2	−0·1	1347·67	975·00	+ 7·7	+15·9	−27·6
VII. The northern agricultural and mining counties	27·9	26·5	−1·4	65·8	67·2	+1·4	5·8	6·0	+0·2	0·5	0·3	−0·2	1079·66	815·35	−10·6	−12·0	−24·5
Total of the most instructed districts	27·3	27·7	+ 0·4	61·1	61·0	− 0·1	11·3	11·0	−0·3	0·3	0·3	......	8839·66	8656·34	−12·8	− 8·3	− 2·1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23816·67	20698·00	......	......	−13·2

Statistics of Mendicancy.
By Sir J. P. BOILEAU, *Bart.*, *F.R.S.*, *V.P. Stat. Soc.*

The writer regretted that there were no means at present of attaining a general view of the statistics of mendicancy for the United Kingdom. It might be useful in the mean time to examine some tables drawn up from the books of the Mendicity Society of London, which show the progress which Irish mendicancy has made on that Society. The number of meals given to Irish in January 1828, was 379, whilst in January 1848 the number was 21,578; which being divided by 4, allowing each individual four meals a month, would show that 5396 individuals were relieved, and indicate the enormous increase of about 5300, or 53 upon 1. From the Society's books it appears that 50 per cent., or half of the 5396, were grown-up persons, while in 1828, following the same rule, they amounted to 17½. While Irish mendicancy appears to have so much increased, English mendicancy does not seem to have varied since 1828; it had in fact decreased in 1832-33 and in 1837-38. The increase in Irish mendicancy was probably to be attributed to severe winters, the late failures of the potato crop, the establishment of refuge-houses and soup kitchens in the metropolis, and the alteration in the poor law of 1837. Before that period it was the practice to refuse admittance to Irish vagrants into the unions of the metropolis; since then it was considered that Irish vagrants had as good a legal right to relief as any other persons. Another cause assigned as contributing to the influx of Irish into London was, that the low lodging-housekeepers found means of obtaining tickets from the Mendicity Society, and of offering them as orders for food to those who would lodge with them. These causes induced old mendicants to flock to London. This view of the case was supported by statistical proof exhibited in tables. These were considered the most probable causes of the increase in Irish mendicancy. The remedies suggested to meet the evils were to discontinue the establishments which held out food to mendicants without inquiry as to character or the want of labour, and to place the establishment of district relieving-houses under the superintendence of the police.

Facts bearing on the Progress of the Railway System of Great Britain.
By W. HARDING, *C.E.*

Contributions to Academical Statistics.
By the Rev. B. POWELL, *F.R.S. Sav. Prof. of Geom., Oxford.*

On the desirableness of extending to the Working Classes the opportunity of purchasing deferred annuities, as a provision for old age. By CADOGAN WILLIAMS.

Moral and Educational Statistics of England and Wales. By JOSEPH FLETCHER, *Hon. Sec. Statistical Society of London.*

[The abstract of this paper, which was read in 1847, was received too late for the volume of that year.]

As it is of the whole kingdom that I purpose to speak, it is of the *public* enumerations that I must now chiefly make use; and by the nature of the subject I am required to use principally the last Census of the Population; the Income Tax Returns; the Reports of the Registrar-General of Births, Deaths, and Marriages; the Home-Office Tables of Criminal Offenders; the latest Reports of the Poor-Law Commissioners; and a Summary of Savings Banks, published by the barrister appointed to certify their rules. It is by the agency of such departments as produce these documents that the State takes cognizance of all or of certain classes of its subjects, at various periods, and under the occurrence of very dissimilar events; and from the records of this momentary cognizance the following results are derived; while many more of equal interest may be obtained by those who have the desire and the opportunity to elaborate them. I contribute on the present occasion only the results of some first efforts, which, if they serve to indicate the direction in which another may profitably proceed, will not have been made in vain.

Comparison of the different Districts of England and Wales, with reference to Population, Real Property, Persons of Independent Means, Instruction, Ignorance, Improvidence, Crime, and Savings, abstracted from the larger Table annexed.

Divisions. DISTRICTS AND COUNTIES.	Inhabitants. Population in 1841.	Real Property. Proportion per cent. of real property assessed to the Income Tax in 1843, above and below the average to the like population in England and Wales.	Realized Properties. Proportion per cent. of persons of independent means in 1841, above and below the average of all England and Wales, upon the like population.	Progress of Instruction. Excess or deficiency per cent. of the men signing the marriage register with marks in 1844, as compared with 1839—40, in each county.	Ignorance. Proportion per cent. of the men signing the marriage register with marks in 1844, above and below the average of all England and Wales, upon the like number of marriages.	Improvident Marriages. Proportion per cent. of marriages under 21 years of age in 1844, above and below the average of all England and Wales, upon the like number of marriages.	Bastardy. Proportion per cent. of the births registered in 1842, which were of illegitimate children above and below the average of all England and Wales upon the like number of registered births.	Pauperism. Proportion of paupers relieved in 1844, above and below the average of all England and Wales upon the like population.	Savings. Proportion per cent. of deposits in Savings Banks 20th November 1844, above and below the average to the like population in all England and Wales in 1841.	Criminal Commitments. Proportion per cent. of commitments above and below the calculated average for all England and Wales, on the same amount of male population of the like ages, in 1842—44.
I. *Southern Agricultural and Maritime Counties.*										
I.A. Counties of least Instruction:—										
Sussex	299,753	+ 3·71	+ 6·1	−3·	− 7·5	+ 3·7	+ 0·6	+43·0	− 7·7	− 3·4
Hants	355,004	− 2·87	+18·1	−3·	−11·1	− 60·1	− 4·6	+22·2	+ 1·2	− 1·3
Dorset	175,043	−13·24	+13·9	+2·	+10·1	+ 26·1	− 0·2	+43·0	+56·6	−19·2
Total	829,800	− 4·93	+12·9	−2·1	− 5·9	− 12·0	− 1·1	+34·5	+ 9·6	− 6·0
I.B. Counties of most Instruction:—										
Kent	548,337	− 1·69	+21·1	−1·	−17·1	− 40·9	−13·0	+ 1·1	+14·5	+21·4
Devonshire	533,460	−10·01	+36·0	+1·	−11·9	− 54·3	−24·2	+ 0·8	+86·4	−24·7
Total	1,081,797	− 5·79	+28·5	...	−14·3	− 47·9	−18·4	+ 0·9	+49·9	− 0·26
Balance on the side of least Instruction	...	·86	...	2·1	Difference.	...	...	...	...	5·74*
Balance on the side of most Instruction	...	...	15·6	...	8·4	35·9	17·3	33·6	40·3	
Total Southern Agricultural and Maritime Counties	1,911,597	− 5·42	+21·7	−0·9	−10·8	− 32·8	−11·2	+14·6	+32·4	− 2·8
II. *South Midland and Eastern Agricultural Counties.*										
II.A. Counties of least Instruction:—										
Suffolk	315,073	+ 1·07	−15·1	−2·	+42·0	+ 17·3	+20·1	+36·2	−23·6	+12·3
Cambridge	164,459	+24·27	−17·0	−5·	+33·5	+103·8	+ 7·3	+27·5	−44·5	− 6·2
Norfolk	412,664	+ 4·55	−10·4	...	+38·1	+ 28·9	+47·2	+29·6	−14·8	+14·9
Essex	344,979	+ 4·02	−23·4	−4·	+42·4	+ 38·6	−21·2	+50·0	−13·5	+27·9
Huntingdon	58,549	+27·19	−29·5	−1·	+38·0	+115·1	−23·9	+ 8·9	−32·7	−30·4
Total	1,295,724	+ 7·09	−16·7	−2·5	+39·3	+ 42·7	+13·9	+36·4	−21·1	+13·3

Wiltshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oxford	161,643	+17·60	−14·9	−3·	+ 5·0	+ 7·8	+11·4	+46·9	+20·9	+12·9
Berkshire	161,167	+11·30	+ 5·7	+2·	+28·6	− 3·3	+ 9·1	+19·0	+49·6	+ 9·6
Total	581,523	+ 8·94	−10·2	−2·	+21·0	+ 30·1	+ 9·5	+46·1	+22·3	+11·4
Balance on the side of least Instruction	...	...	...	·5	Differ-ence. 18·3	...	...	9·7		
Balance on the side of most Instruction	...	·85	6·5	...		12·6	4·4	...	43·4	1·9
Total South Midland and Eastern Counties	1,877,247	+ 7·66	−14·7	−2·2	+33·8	+ 38·8	+12·6	+39·5	− 7·6	+12·7
III. *Metropolitan Counties* (both of the highest rate of instruction):—										
Middlesex	1,576,636	+33·41	+72·6	...	−59·7	− 62·8	−48·8	−12·0	+81·8	− 4·9
Surrey	582,678	− 6·49	+50·1	+1·0	−53·2	− 61·6	−48·0	−13·3	−15·2	+57·3
Total	2,159,314	+22·64	+66·6	...	−58·1	− 62·5	−48·5	−12·5	+55·6	+11·3
IV. *North Midland and North Eastern Agricultural Counties.*										
IV.A. Counties of least Instruction:—										
Herefordshire	113,878	+31·10	+ 2·6	−3·	+11·2	− 45·9	+58·3	+ 1·5	+23·0	+19·3
Shropshire	239,048	+14·41	−20·6	−4·	+24·6	− 46·7	+38·0	− 2·9	+60·3	+12·7
Total	352,926	+19·79	−13·1	−3·3	+20·7	− 46·0	+43·9	− 1·2	+48·3	+14·8
IV.B. Counties of most Instruction:—										
Lincolnshire	362,602	+56·87	−10·5	−2·	− 1·5	+ 3·9	− 6·5	−19·2	− 8·4	−19·6
Northamptonshire	199,228	+16·51	−32·2	−1·	+15·6	+ 57·9	− 5·4	+20·1	−14·5	−10·9
Rutland	21,302	+36·62	−30·3	−8·	−38·4	− 67·0	+ 0·8	+ 3·5	...	+ 1·9
Total	583,132	+35·98	−18·6	−1·1	+ 3·7	+ 21·9	− 5·8	− 4·9	−13·9	−15·9
Balance on the side of least Instruction	...	...	...	2·2	Differ-ence. 17·0	67·9	...	...	62·2	
Balance on the side of most Instruction	...	16·19	5·5	...		...	49·17	3·7	...	30·7
Total North Midland and North-Eastern Agricultural Counties:—	936,058	+29·98	−16·5	−1·7	+ 9·5	− 1·0	+10·2	− 3·6	+ 8·7	− 4·3

* Arising from one of the lowest districts of the Metropolis being included in Kent.

Table (continued).

Divisions.	Inhabitants.	Real Property.	Realized Properties.	Progress of Instruction.	Ignorance.	Improvident Marriages.	Bastardy.	Pauperism.	Savings.	Criminal Commitments.
DISTRICTS AND COUNTIES (*continued*).	Population in 1841.	Proportion per cent. of real property assessed to the Income Tax in 1843, above and below the average to the like population in England and Wales.	Proportion per cent. of persons of independent means in 1841, above and below the average of all England and Wales, upon the like population.	Excess or deficiency per cent. of the men signing the marriage register with marks in 1844, as compared with 1839—40, in each county.	Proportion per cent. of the men signing the marriage register with marks in 1844, above and below the average of all England and Wales, upon the like number of marriages.	Proportion per cent. of marriages under 21 years of age in 1844, above and below the average of all England and Wales upon the like number of marriages.	Proportion per cent. of the births registered in 1842, which were of illegitimate children above and below the average of all England and Wales, upon the like number of registered births.	Proportion of paupers relieved in 1844, above and below the average of all England and Wales, upon the like population.	Proportion per cent. of deposits in Savings Banks 20th November 1844, above and below the average to the like population in all England and Wales in 1841.	Proportion per cent. of commitments above and below the calculated average for all England and Wales, on the same amount of male population of the like ages in 1842—44.
V. *South Midland Agricultural Counties, with domestic Manufactures.*										
V.A. Counties of least Instruction:—										
Bedfordshire	107,936	−11·12	−43·1	−4·	+53·0	+147·8	+15·1	+26·9	−23·0	+21·4
Buckinghamshire	155,983	− 1·60	−29·5	−4·	+30·2	+ 69·0	+ 8·8	+49·7	−43·0	+20·0
Hertfordshire	157,207	+ 0·21	−16·1	−2·	+53·8	+112·5	+ 4·6	+17·5	−46·2	+14·2
Total	421,126	− 3·36	−28·0	−3·6	+45·9	+109·5	+ 9·0	+30·5	−39·1	+18·2
V.B. County of most Instruction:—										
Somersetshire	435,982	+27·21	+21·9	−1·	+10·6	+ 6·5	− 7·3	+25·8	+ 6·3	+37·6
Total	435,982	+27·21	+21·9	−1·	+10·6	+ 6·5	− 7·3	+25·8	+ 6·3	+37·6
Balance on the side of least Instruction	...	...	...	2·6	{ Difference. 35·3 }	...	...	..	...	19·4
Balance on the side of most Instruction	...	30·57	49·9	...		103·0	16·3	4·7	45·4	
Total South Midland Agricultural and Manufacturing Counties	867,108	+12·18	− 2·5	−2·2	+27·3	+ 55·2	+ 0·9	+28·1	−15·9	+28·1
VI. *Western (and chiefly Celtic) Agricultural and Mining Counties.*										
VI.A. Counties of least Instruction:—										
South Wales	515,283	−31·32	+ 4·9	−2·	+39·3	− 32·3	+ 3·4	− 6·5	−65·3	−55·7
North Wales	396,320	−27·17	−20·7	−6·	+26·1	− 30·0	+12·3	+28·8	−50·7	−61·2
Monmouthshire	134,355	−18·44	−30·4	−3·	+53·3	− 38·8	−31·3	−32·4	−56·7	−12·1
Total	1,045,958	−28·09	− 9·3	−3·7	+36·8	− 32·4	+ 1·1	+ 2·3	−58·7	−51·3

VI.B. County of most Instruction:— Cornwall	341,279	−26·48	− 5·1	+0·6	+11·8	− 12·7	−36·7	−29·2	− 4·0	−54·1
Total	341,279	−26·48	− 5·1	+0·6	+11·8	− 12·7	−36·7	−29·2	− 4·0	−54·1
Balance on the side of least Instruction	...	...	...	4·3	Difference. 25·0	− 19·7				
Balance on the side of most Instruction	...	1·61	4·2	...		...	37·8*	31·5	62·7	2·8
Total Western (and chiefly Celtic) Agricultural and Mining Counties	1,387,237	−27·70	− 8·3	−2·8	+30·9	− 27·6	− 8·8	− 5·5	−45·2	−51·9
VII. *Northern Agricultural and Mining Counties.*										
VII.A. Counties of least Instruction:—										
Westmoreland	56,454	+ 9·84	+43·7	−1·	−36·2	− 38·1	+37·8	+18·9	−70·9	−66·3
North Riding	204,122	−12·60*	+11·6	−1·	−31·4	− 43·2	+26·1	−10·6	+10·5	−23·4
Durham	324,284	− 4·58	− 9·4	−4·	−29·1	− 26·3	−15·9	−11·9	−59·6	−49·0
Total	584,860	− 6·02	+ 3·0	−2·7	−30·4	− 32·3	+ 2·6	− 8·4	−36·2	−41·8
VII.B. Counties of most Instruction:—										
Cumberland	178,038	− 5·21	+32·1	...	−52·1	− 25·7	+70·3	−31·1	−23·2	−68·2
East Riding (with city and ainsty)	233,257	+12·69*	+16·7	−1·	−37·1	− 31·9	+ 1·9	− 8·4	+83·6	−23·4
Northumberland	250,278	−14·25	− 2·0	−3·	−51·3	− 8·1	+ 1·2	− 1·0	+18·7	−46·3
Total	661,573	− 0·48	+13·8	−1·3	−45·1	− 22·2	+19·1	−11·8	+30·3	−43·8
Balance on the side of least Instruction	...	...	...	1·4	Difference. 14·7	10·1	16·5			
Balance on the side of most Instruction	...	5·54	10·8	...		...	...	3·4	66·5	2·0
Total Northern Agricultural and Mining Counties	1,246,433	− 3·08	+ 8·7	−1·9	−38·2	− 26·9	+11·3	−10·2	− 0·9	−42·8

* The real property and crime of the several ridings of Yorkshire appear to be the same, simply because the returns are made only for the whole of that county without distinguishing the ridings, though each of them is equal to some of the whole counties.

Table (continued).

Divisions.	Inhabitants.	Real Property.	Realized Properties.	Progress of Instruction.	Ignorance.	Improvident Marriages.	Bastardy.	Pauperism.	Savings.	Criminal Commitments.
DISTRICTS AND COUNTIES (*continued*).	Population in 1841.	Proportion per cent. of real property assessed to the Income Tax in 1843, above and below the average to the like population in England and Wales.	Proportion per cent. of persons of independent means in 1841, above and below the average of all England and Wales, upon the like population.	Excess or deficiency per cent. of the men signing the marriage register with marks in 1844, as compared with 1839—40, in each county.	Proportion per cent. of the men signing the marriage register with marks in 1844, above and below the average of all England and Wales, upon the like number of marriages.	Proportion per cent. of marriages under 21 years of age in 1844, above and below the average of all England and Wales, upon the like number of marriages.	Proportion per cent. of the births registered in 1842, whichwere of illegitimate children above and below the average of all England and Wales, upon the like number of registered births.	Proportion of paupers relieved in 1844, above and below the average of all England and Wales, upon the like population.	Proportion per cent. of deposits in Savings Banks 20th November 1844, above and below the average to the like population in all England and Wales in 1841.	Proportion per cent. of commitments above and below the calculated average for all England and Wales, on the same amount of male population of the like ages in 1842—44.
VIII. *Northern and Midland Mining and Manufacturing Counties**.										
VIII.A. Counties of least Instruction:—										
Cheshire	395,660	—11·45	—23·8	—4·	+ 0·4	+ 39·6	+40·3	—30·0	3·5	+34·5
Lancashire	1,667,054	—13·74	—38·9	+1·	+22·1	+ 7·8	+28·8	—14·5	—19·7	+10·1
West Riding	1,154,101	—12·69†	—33·4	—3·	+17·9	+ 67·8	+ 5·3	—19·6	—34·9	—23·4
Staffordshire	510,504	—11·33	—42·9	...	+31·3	+ 34·0	+10·2	—25·8	—36·5	+22·7
Worcestershire	233,336	+ 5·87	—20·0	...	+37·3	+ 17·2	— 7·3	—12·2	+12·9	+54·7
Total	3,960,655	—11·74	—31·0	—0·9	+21·5	+ 29·6	+18·1	—18·9	—22·7	+ 6·9
VIII.B. Counties of most Instruction:—										
Derbyshire	272,217	— 6·08	—31·9	—4·	—13·6	+ 9·5	+20·6	—44·4	—18·0	—32·7
Gloucestershire	431,383	—10·85	+32·3	—2·	—13·2	— 5·1	— 9·5	— 3·0	+25·4	+54·0
Warwickshire	401,715	+ 9·11	—20·3	—1·	+ 0·2	+ 0·1	—23·7	—23·9	—22·1	+39·0
Leicestershire	215,867	+18·00	—27·7	—2·	— 2·8	+110·5	+ 6·9	+18·1	—43·2	+40·3
Nottinghamshire	249,910	—15·26	—31·2	...	+ 1·9	+ 58·4	+46·8	—26·0	+12·8	+12·5
Total	1,571,092	— 1·63	—10·6	—1·8	— 5·6	+ 26·7	+ 4·1	—15·1	— 5·7	+22·5
Balance on the side of least Instruction	...	...	...	...	Difference. 27·1	...	...	...	...	15·6
Balance on the side of most Instruction	...	10·11	20·4	·9		2·9	14·0	3·8	17·0	
Total Northern and Midland Mining and Manufacturing Counties	5,531,747	— 8·87	—25·2	— ·9	+14·9	+ 28·9	+14·6	—17·8	—17·9	+11·2

* It is very difficult to divide these counties into separate groups; but the greater crime going with the more southern, speaks favourably in this one respect for the *factory* districts, though the general result is very unfavourable to the *manufacturing*.

† The real property and crime of the several ridings of Yorkshire appear to be the same, simply because the returns are made only for the whole of that county without distinguishing the ridings, though each of them is equal to some of the whole counties.

The metropolitan and the southern agricultural and maritime counties, which are two out of the three of highest instruction, are the only two in which improvident marriages, or those of men under twenty-one and illegitimacy, are both under the average. In every other, the deficiency of the one ill feature is just counterbalanced by the prevalence of the other, except in the case of the great central mining and manufacturing region, which has an unhappy excess of both. I have given the illegitimacy at two different periods, and from two distinct authorities, because they materially disagree in one particular: namely, the extent to which this unhappy feature of society prevails among the Celtic populations of the west; in which respect I incline to agree with the older authority, because of its greater claim to accuracy in regard to this one point. It is, I think, only the omission of a large number from this district which makes the south midland agricultural and manufacturing counties just above the average in the more recent statement, though it will not account for all the relative increase of illegitimacy in the south midland and eastern agricultural counties.

In the pauperism columns, the balance is just against ignorance, but averages of this date show merely the usual state of things in a time of manufacturing prosperity, when every one in the manufacturing regions that can and will work is employed; and all wanting employment in the neighbouring agricultural districts are easily drafted off; while the more southern, distant, and purely agricultural regions are still oppressed by nearly their usual excess of people upon the rates, even in the case of those counties which have some little of manufactures intermingled with their agriculture; for they are of such a nature as inevitably to encourage a faster increase of hands than of trade to employ them.

With regard to providence, as tested by the accumulations in the savings banks, it will be seen that the excess is variously coincident with the superiority of instruction, except in the case of the northern agricultural and mining districts, where the amount falls just below the average, in proportion to the population, perhaps unusually depressed by the great colliers' strike, which was at its most desperate shifts at the period of the returns. Notwithstanding the high wages of the mass of the population in the midland mining and manufacturing regions in all good times, therefore, the rate of saving is as low as in the wretched districts of Bucks, Herts, and Bedfordshire. The lowest amount in savings banks is in Wales. The circuit of deposit for each bank will sometimes overstep a county boundary, but averages of the present magnitude will not be much diverted from accuracy by such a circumstance; and indeed the county boundaries do not generally run near to the towns in which the banks are chiefly situated; but when we come to consider the subdivisions of these several districts, and especially the counties individually, cases of disturbance from these causes will be obvious.

The columns of committals for criminal offences agree very nearly with those of the early marriages; and after deducting the dispersed populations of the Celtic and the Scandinavian regions, both remarkably deficient in crime, the Welsh districts especially; and the southern agricultural and midland and north-midland agricultural counties, which are also on the favourable side of the average, the excess of about 12 per cent. on the remainder of the population, is pretty nearly distributed throughout the rest of the kingdom, except where this proportion is more than doubled in the wretched south midland agricultural and manufacturing counties; the general result against which is very marked.

These results as completely extinguish our belief in rural innocence, as those already recited undeceive us as to the comparative excess of rural ignorance. A relative excess of ignorance, greater concentration of numbers, a low proportion of the leisured classes, and employment in *dispersed* manufactures, appear therefore to be the concomitants of the excess of crime everywhere but in the metropolitan counties, where its surprisingly small excess, though it may in some degree be owing to the preventive character of its superior police, offers a high testimony in favour of the general conduct of its more instructed population.

If now we descend one step from these large results, and divide each of these great districts into two portions, according to the greater or less amount of, at least, rudimentary instruction which prevails amongst its inhabitants, we shall find the general conclusions at which we have arrived corroborated by the results of this analysis wherever we apply it. And that the instruction test is the wand to employ for effecting this new combination must be obvious, if it be regarded as the best avail-

able indication, under the existing circumstances of society, of the relative degree of attention which the mass of the population has received from the more educated classes in each district, or of a superior energy of character and independence of circumstances hereditary in the inhabitants of a whole district. A faltering of the figures to declare in favour of the counties of most instruction occurs scarcely anywhere but among the northern and midland mining and manufacturing counties. Here the lowest proportion of crime is found in the counties which are most notorious for their largest amount of factory population, viz. Lancashire, the West Riding of Yorkshire, Derbyshire, and Nottinghamshire, while the most criminal are Cheshire, Staffordshire, Worcestershire, Gloucestershire, Warwickshire, and Leicestershire, on the whole more noted for dispersed and domestic manufactures. The first-mentioned counties, however, are low in every other feature brought to account; and yet a greater diffusion of instruction is seen to be the concomitant of every promising figure.

Vital Statistics of a District in Java. By JOHN CRAWFORD, *F.G.S.; with preliminary remarks upon the Dutch possessions in the East, by* COLONEL SYKES, *V.P.R.S.*

In connexion with Mr. Crawford's paper Colonel Sykes gives a general view of the progress of population in Java,—of the extraordinary development of the commercial and agricultural industry of the Dutch in the East; and of the vast extent of the domains which they claim. The total area of the eastern archipelago, including Java, Sumatra, Borneo, Celebes, the Moluccas and the other islands, is 31,428 square geographical leagues, of which the Dutch claim 25,872, or five-sixths of the whole, comprising a population of above twenty-five millions of souls, ruled by a few Europeans. The progress of the population in Java is remarkable. By successive censuses it appears that it has risen from 6,368,090 souls in 1824 to 9,542,045 in 1845: commerce and agriculture progress in a greater ratio. In 1826, the coffee exported was 340,049 picals of 125 lbs. each, in 1843 it was 1,018,102. Sugar, 19,795 to 929,769 picals for the same period. Indigo, from 76 picals to 1,890,429 lbs.! Tin, from 13,800 picals to 45,705 picals: other products are also remarkable in their increase. From a communication of the Colonial Minister to the second chamber of the States-General in 1844, the total receipts of Netherland India were 81,784,671 florins.

Mr. Crawford's paper contained the vital statistics of a district in Java for one year. In the city and neighbourhood of Yugyakarta, to which locality the observations were chiefly confined, the births were fewest and the mortality greatest in the town; while the opposite state of things prevailed in the country, and especially in the more elevated part. The author inferred from the data which he had collected, that a native population under the tropics, in the enjoyment of peace, with a fair share of industry, a sufficiency of fertile land and a favourable climate, may increase as an European one in a temperate climate with similar advantages.

On the Annual Increase of Property, and of Exports and Imports in Canada. By JOSEPH HUME, *M.P. (communicated by* J. FLETCHER.)

These statements demonstrate the great rapidity with which the most valuable and permanent species of wealth accumulates in Canada, and the extent to which the province is already able to consume and employ goods of various kinds sent from this country, and to pay for them by its exports to Great Britain and its dependencies. That power will henceforth increase annually, at a rate greatly exceeding that of former years, under the influence of a principle long recognised.

The rateable property in Upper Canada amounted in 1825 to £997,025; in 1840 to £5,691,477; in 1841 to £5,996,609; in 1842 to £6,375,140; in 1843 to £5,916,162; and in 1844 to £7,139,901, according to the assessment returns for the last three years.

In the United Province of Upper and Lower Canada, the imports into Canada by sea, from 1838 to 1847 inclusive, increased.

On comparing a few of the more important articles of import by sea for the years 1846 and 1847, the following results are obtained:—Against 313,076 gallons of

wine imported in 1846, there are 229,595 gallons in 1847. In spirits of all kinds, exclusive of whiskey and East and West India rum, 159,547 gallons in 1846, against 185,367 gallons in 1847. In molasses 151,675 gallons, against 365,450 gallons. In refined sugar 895,046 lbs., against 880,305 lbs. In Muscovado and bastard sugars 8,546,982 lbs., against 8,719,099 lbs. In coffee 105,282 lbs., against 261,144 lbs. In tea 603,038 lbs., against 816,866 lbs. In salt 345,396 bushels (equal to 11,513 tons), against 87,880 bushels (equal to 2929 tons). And in goods paying *ad valorem* duties £2,241,154 sterling, against £1,783,682 sterling.

On comparing the exports of 1846 with those of 1847, it will be seen that the exports of the agricultural staples of Canada exhibit a steady increase. For instance, the export of flour in 1846 was 555,602 barrels, against 651,030 barrels in 1847. The export of wheat was 534,747 bushels in 1846, against 628,001 bushels in 1847. That of oatmeal, 5930 barrels against 21,999 barrels. That of oats, 46,060 bushels against 165,805 bushels. And that of butter, 786,701 lbs. against 1,036,555 lbs. Of ashes, however, and timber, there was a falling off, but it was probably more than compensated by an increased export inland.

On the Distribution of the Population of Great Britain and Ireland; illustrated by Maps and Diagrams. By AUGUSTUS PETERMANN, *F.R.G.S.*

A map of the British Isles was exhibited, showing by shading the various degrees of density of population in every part of the United Kingdom; certain districts containing less than 5, others upwards of 2000 inhabitants to 1 English square mile. The causes of this very unequal distribution of the people were alluded to, and tables exhibited giving the density of population in the different parts of the United Kingdom. It was remarked that of the 122 counties and islands,—

3	showed	an average	density	of	1000 souls and upwards to 1 Engl. sq. mile.	
[illegible]	,,	,,	,,	from	1000 to 500	,,
8	,,	,,	,,	,,	500 to 400	,,
9	,,	,,	,,	,,	400 to 300	,,
38	,,	,,	,,	,,	300 to 200	,,
33	,,	,,	,,	,,	200 to 100	,,
26	,,	,,	,,	below	100	

All towns containing 3000 inhabitants and upwards were indicated on the map according to an arrangement of the number of their inhabitants.

Synoptical Table of the Number and Total Population of all Towns containing 10,000 Inhabitants and upwards.

	Towns of 100,000 inhabitants and upwards.		Towns from 50,000 to 100,000 inhabitants.		Towns from 20,000 to 50,000 inhabitants.		Towns from 10,000 to 20,000 inhabitants.		All towns of 10,000 inhabitants and upwards.	
	No.	Total Pop.	No.	Total Pop.	No.	Total Pop.	No.	Total Pop.	No.	Total Pop.
England......	4	2,407,423	8	493,330	43	1,307,564	78	1,052,704	133	5,261,021
Wales.........	...	...	...	...	1	21,929	3	37,698	4	59,627
Scotland......	2	412,506	2	123,841	3	110,994	5	67,414	12	714,755
Ireland........	1	232,726	2	156,028	2	71,607	12	158,642	17	619,003
Islands in the British Seas	...	...	...	...	1	21,040	1	15,220	2	36,260
Un. Kingdom.	7	3,052,655	12	773,199	50	1,533,134	99	1,331,678	168	6,690,666

Considerable pains have been taken to separate the population of the distinct place from that of the whole parish. In England however this has not always been possible; as the population returns do not afford the means of making any such separation. The summary for England therefore can only be considered as approximately correct.

Statistics of Brittany and the Bretons.
By JOSEPH FLETCHER, *Hon. Sec. Statistical Society of London.*

This paper was an abstract of the report of a tour in the five departments of Brittany during the years 1840 and 1841, under instructions from the Academy of the Moral and Political Sciences, made by MM. Beniston de Chateauneuf and Villermé, members of that Academy, and contained in the fourth volume of the Memoirs of the Academy of the Moral and Political Sciences. It described the surface of the great peninsula of Brittany, projecting into the ocean between the Bay of Biscay and the English Channel, to comprise 1715 square leagues (the French league of length being 2½ English miles), or 3,388,850 hectares of 2½ English acres. Its central parts are occupied in great measure by a double range of mountains of no great elevation. Breton cultivation, on the borders of the province, is intelligent, advanced and productive; in the interior, it is ignorant, prejudiced and unproductive. In the two entire departments of Finistère and Morbihan, there are more heaths than cultivable land; and it is of course in these wilder regions, with those of the department of the Côtes-du-Nord, that the old manners, habits and customs of the country are most tenaciously retained. The sources of the reputed poverty and backwardness of the province being the especial object of the inquiry, the especial attention of the travellers was given to the poorest and most backward departments.

Table of the cultivation of Brittany, as compared with that of all France, abstracted from the Official Statistics of Agriculture.

Occupation of the surface.	Brittany.		France.	
	Hectares.	Proportion.	Hectares.	Proportion.
Wheat	269,888	$\frac{1}{13}$ to $\frac{1}{12}$	5,586,787	$\frac{1}{9}$
Other grain	491,010	$\frac{1}{7}$	8,313,478	$\frac{1}{6}$
Buckwheat	272,541	$\frac{1}{12}$	651,212	$\frac{1}{81}$
Potatoes	65,069	$\frac{1}{52}$	92[illegible],971	$\frac{1}{59}$
Hemp and flax	34,917	$\frac{1}{100}$	274,389	$\frac{1}{200}$
Orchards, nurseries, and osier-beds	56,904	$\frac{1}{59}$	766,578	$\frac{1}{68}$
Gardens and lands under various vegetables,—colewort, turnips, beet-root, tobacco, &c.	38,742	$\frac{1}{87}$	896,747	$\frac{1}{59}$
Vines	27,728	$\frac{1}{125}$	1,972,340	$\frac{1}{27}$
Natural meadows	301,861	$\frac{1}{11}$	4,198,198	$\frac{1}{13}$
Artificial meadows	50,880	$\frac{1}{67}$	1,576,567	$\frac{1}{33}$
Woods and forests	100,154	$\frac{1}{17}$	8,804,551	$\frac{1}{6}$
Fallows	429,053	$\frac{1}{8}$	6,763,281	$\frac{1}{8}$
Pasturages, Heaths, &c.	976,034	$\frac{1}{4}$ to $\frac{1}{3}$	9,191,076	$\frac{1}{6}$
Total surface, including roads, &c.	3,388,843	....	52,768,600	....

The Breton sows for the first year buckwheat, which is his own principal food; the second, wheat; the third, barley or oats, or often wheat again, of which he thus takes two crops in succession, and then he leaves it bare, except of self-sown weeds, for three, four, and five years, and often much longer: replying to every argument in favour of green crops, with all the firmness of conviction, that the land requires rest as well as the arms that cultivate it. Under such a system, the peculiar Breton custom of tenant-right to compensation for improvements has not proved a panacea for a distress frequently as great as that of Ireland.

The cattle are very poor and inferior,—an ox weighing from 50 to 260 kilogrammes of 2½ English pounds; a cow from 40 to 100 kil.; sheep from 10 to 18 kil. The quantity of cattle on the land has greatly declined since 1812. From 10,000 to 15,000 horses are sent annually out of the country for the service of the artillery, cavalry, and diligences. The commercial industry of Brittany is almost wholly in agricultural produce (of which it exports all the best), in grain, hemp, flax, cattle and horses, and less important articles, such as honey, bees'-wax and butter. Salt from the neighbourhood of Nantes, oysters from the Bay of Cancale, and pilchards from

the bays of Douarnenez and Concarneau, are exported in considerable quantities. A certain number of ships are annually equipped to the shores and banks of Newfoundland; and there is a considerable manufacture of the flax and hemp grown within the province; but an obstinate adherence to old instruments and methods, and a positive rejection of better, has gradually reduced both spinners and weavers to the most abject misery, in competition with the improved processes and growing combinations of capital in the world around them. Exclusive of the weeding of the flax, the culture and manufacture of one hectare (2½ acres) of either flax or hemp, costs 4483 days' labour, distributed as follows :—

Processes.	Days.	Agency.	Francs per day.	Total francs.
Agriculture	296	Men and horses at...	0·75	221·00
Dressing	700	Men and women......	0·40	280·00
Spinning	2666	Women	0·22	599·85
Winding, warping, &c......	164	Women	0·50	82·00
Quill-winding	143	Children	0·29	41·47
Weaving	287	Men	1·00	287·00
Bleaching	90	Men	0·75	67·50
Getting-up and despatching	137	Men	0·75	102·75
Rent of a hectare of land fit for the cultivation of flax or hemp			100·00	
Half the price of the seed (that which is gathered being worth the other half)			57·00	326·00
Profit of the cultivator or farmer			169·00	
Fuel and ashes for the bleaching				35·00
Total.....................				2042·00

Thus the mere cultivation costs 27 per cent. of the whole value; dressing, 14; spinning, 29; weaving, 20; bleaching, 5; getting up and despatching, 5. Under flax there are 20,357 hectares; under hemp, 14,560—making a total of 34,917; and the average produce of each hectare of flax, after the removal of the rind, is from 2000 to 2500 kil. of dry stalks. With the largest and coarsest hemp is made cordage; with the finer, sailcloth; and with the hemp and flax united, coarse linens. There is likewise a dwindling woollen manufacture at Vitré, &c.

The population of Brittany in 1800, was 2,202,700; in 1831, 2,574,000; in 1836, 2,620,300; in 1841, 2,666,200. The increase from 1830 to 1835 inclusive was 30 per cent. in Loire-Inférieure, 25 in Finistère, 22 in Ille-et-Vilaine, 20 in Côtes-du-Nord, and only 12 in Morbihan; the average in all Brittany being 19 per cent. In France generally it has been 22, while the increase in England and Wales is more than double even the latter rate.

Notwithstanding this slow increase of population in Brittany, its actual amount, in even the most waste and uncultivated departments, is greater in proportion to the total surface than in France generally, including its most fertile provinces: the average in all France being 1256 inhabitants per square league, while in Morbihan it is 1270, Loire-Inférieure 1364, Ille-et-Vilaine 1618, Finistère 1623, Côtes-du-Nord 1781, and all Brittany 1528. Two-thirds of this population is dispersed over the surface of the country on small properties, small tenancies, and cottage holdings; the proportion of town population being small as compared with France generally. Out of 540,000 houses in the whole department, 400,000 have only two or three openings, *i. e.* one or two besides the door.

Movement of the population in Brittany and in all France, 1831 to 1836.

	Brittany.		France.
Mean population............	2,597,230	......	33,055,060
One birth to	30·68	......	33·90
One death to	33·68	......	38·60
One marriage to	130·00	......	127·00
Births to each marriage...	4·19	......	3·57
One illegitimate birth to...	30·12	......	13·81

The maximum of births, deaths and marriages to the population falls in Finistère, and the maximum of children to each marriage in Morbihan (4·51). The average age of the first marriages of the men is 28 years and 4 months, and of the women 25 years and 11 months. In England and Wales, the average age of marriage in both sexes, even including second with first marriages in the same average, is decidedly less, being 27 years and 3 months for the men, and 25 years and 3 months for the women.

The exceeding misery of the Breton peasant was noticed by Neckar in 1784, again by Arthur Young ten years later, and relatively to that of the population of the rest of France or of Great Britain, it is as conspicuous as ever. The interior of a Breton cabin in the most Breton departments, is described as a parallel to that of an Irish one; buckwheat bread being the chief sustenance instead of potatoes. The peculiarity of his language appears to be the greatest obstacle to the social advancement of the Breton, and the isolation in which it keeps him perpetuates his ignorance. The sacristans, beadles, and good sisters are still to a great extent, as they were formerly, the sole instructors of the people. Under the republic there were scarcely fifteen elementary schools in all the department, and little advancement was made until within this few years, under the competition of the government schools with those of the "Frères de la Doctrine" and the disciples of M. Lamennais, called the "Petits Frères." M. Guerry reckons only 1 in 96 of the inhabitants to be under instruction; and in the five years 1836–40, 78 per cent. of those arraigned before the criminal tribunals could neither read nor write.

The Statistics of Civil Justice in Bengal in which the Government is a party. By Colonel Sykes, *V.P.R.S.*

The author shows that although the government of India is based upon its military authority, yet it provides that the meanest of its subjects in Bengal shall be able to sue the government, in *forma pauperis* or otherwise, in its own Courts; and though every judge or officer of every Civil Court is appointed by the government, and removable at pleasure, yet the decision both by the native judges, as well as by the European judges, in a multitude of cases are against the government, and bear testimony to the independence and impartiality of the judicial authorities. The author gives numerous cases, illustrative of this fact; showing also that the government is frequently compelled to appeal against the decisions of its lower court to its highest appellate court, and often ineffectually.

The outstanding balances due to government under decrees of Court in 1845–46, were—

Privy Council decrees	233,404	Rs.
Revenue decrees	151,904	,,
Salt and opium decrees	471,727	,,
Military department	7,196	,,
Post-office	184	,,
	864,415	,,
Pauper suits	344,626	,,

In 1846–47, the outstanding balances were—

Revenue decrees	191,631	,,
Salt and opium decrees	511,331	,,
Privy Council decrees	155,123	,,
Pauper suits' decrees	304,564	,,

A considerable proportion of these sums would be irrecoverable.

MECHANICS.

Mr. J. Ashman exhibited an artificial leg, of an improved construction.

On Improvements in the Reflecting Circle, more particularly in reference to an instrument for the purpose of measuring angular distances of the Sun and Moon. By J. C. Dennis.

So great is the accuracy required in instruments of this kind that it is necessary to distinguish to the 5940th part of an inch. The smallest error of construction therefrom produces a serious error in the observation; and to render the construction more perfect, the following suggestion is made:—Instead of attaching the circle (technically called an arc) to the parts which support it, let the whole be cast in one piece, and then planed, polished or divided, to suit the purposes of modern astronomy.

On the application of Steam Power to the Drainage of Marshes and Fen Lands. By Joseph Glynn, *F.R.S., M.Inst.C.E.*

The steam-engine is used to raise the water above the level of those lands which lie too low to be drained by natural outfall, and also in situations where the fall is not sufficient to carry off the superfluous water in time to prevent damage to the crops.

Mr. Glynn has applied steam power to the drainage of land in fifteen districts, all in England, chiefly in Cambridgeshire, Lincolnshire, and Norfolk. The quantity of land so drained amounts to more than 125,000 acres, the engines employed being seventeen in number, and their aggregate power 870 horses; the form of the engines varies from 20 to 80 horses. Mr. Glynn was also engaged in draining by steam power the Hammerbrook district, close by the city of Hamburg; and in another level near to Rotterdam, an engine and machinery with the requisite buildings have been erected from his plans, by the Chevalier Conrad, and the works successfully carried into effect.

In British Guiana the steam-engine has been made to answer the double purpose of drainage and irrigation. Some of the sugar-plantations of Demerara are drained of the superfluous water during the rainy season and watered during the dry season.

In many of the swampy levels of Lincolnshire and Cambridgeshire much had been done to carry off the water by natural means, and many large cuts had been made and embankments formed, especially in the Bedford Level, which alone contains about 300,000 acres of fen-land; the Great Level of the fens contains about 680,000, formerly of little value, but now rich in corn and cattle.

The Dutch engineers, who were at an early period engaged in these works of drainage, had erected a great number of windmills to raise and throw off the water when the sluices could not carry it away. By the aid of these machines the land was so far reclaimed as to be brought into summer pasture and a precarious state of cultivation producing occasionally crops of wheat. The waters from the uplands and higher levels were intercepted by catch-water drains, which carried away the highland waters, as far as might be practicable, and prevented them from running down upon the fen, from which the excess of rain-water was lifted by the mills. But, as it often happened, when there was most rain there was least wind, so that the wind-engines were often useless when their help was most needed, and the crops were consequently lost.

In this state was the fen-country when the steam-engine was introduced, and by its aid the farmer may now venture to sow wheat with as much confidence, and even more, than upon higher ground; for not only can he throw off the superfluous water at pleasure, but in dry weather a supply can be admitted from the rivers, so that farming in such situations is rendered less precarious than in situations originally more favoured by nature.

It is however to be remarked, that the quantity of rain which falls on those levels on the eastern side of England being much below the general average of the kingdom, the power required to throw off the superfluous water is small when compared with

the breadth of land to be drained, the proportion seldom being greater than 10 horses' power to 1000 acres, and in some cases considerably less.

The general plan is to carry away the water coming off the higher grounds, and prevent it, as much as possible, from running down into the marsh by means of the catch-waterdrains before mentioned, leaving only the rain which falls upon the district to be dealt with by mechanical power.

As the quantity of rain falling on the Great Level of the fens seldom exceeds 26 inches in the year, and about two-thirds of this quantity is carried off by evaporation and absorption or the growth of plants, it is only in extreme cases that 2 inches in depth require to be thrown off by the engines in any one month, which amounts to 1½ cubic feet of water upon every square yard of land, or 7260 feet to the acre.

The standard and accepted measure of a horse's power is 33,000 lbs. raised one foot high in a minute, or 3300 lbs. raised 10 feet high in the same time; and as a cubic foot of water weighs 62½ lbs. and a gallon of water 10 lbs., so one horse's power will raise and discharge, at a height of 10 feet, 330 gallons, or $52\frac{8}{10}$ cubic feet of water in a minute. Consequently this assumed excess of 7260 cubic feet of water fallen upon an acre of land will be raised and discharged at an elevation of 10 feet in about two hours and twenty minutes. If the quantity of land be 1000 acres of fen or marsh, with the upland waters all banked out, the excess of rain, according to the foregoing estimate, will amount to 726,000 cubic feet. A steam-engine of 10-horse power will throw off this water in 232 hours, or in less than 20 days, working 12 hours a day. This calculation has been found fully supported in practice.

Although the rain due to any given month may fall in a few days, yet in such case much of it will be absorbed by the ground; and the drains must be made of sufficient capacity to receive and contain the rain as it falls; besides, in case of necessity, the engine may be made to work 20 hours a day instead of 12, until the danger be past.

The main drains have generally been cut 7½ feet deep and of width sufficient to give them the required capacity to contain the excess of rain, and to bring the water freely down to the engine. In some instances, where the districts are extensive and their length great, it has been found necessary to make them somewhat deeper.

In all cases where it has been requisite to use steam power, Mr. Glynn has applied scoop-wheels to raise the water. These scoop-wheels somewhat resemble the undershot wheel of a water-mill, but instead of being turned by the impulse of the water, they are used to lift it and are kept in motion by the steam-engine.

The floats or ladle-boards of the wheels are made of wood and fitted to work in a trough or track of masonry; they are generally made 5 feet in length, that is to say, they are immersed 5 feet deep in the water, and their width or horizontal dimension varies from 20 inches to 5 feet, according to the power of the engines employed and the head of water to be overcome. The wheel-track at the lower end communicates with the main drain, and at the higher end with the river; the water in the river being kept out by a pair of pointing doors, like the lock-gates of a canal, which close when the engine ceases to work. The wheels themselves are made of cast-iron, formed in parts for convenience of transport. The float-boards are connected with the cast iron part of the wheel by means of oak starts, which are stepped into sockets cast in the circumference of the wheel to receive them.

There are cast-iron toothed segments fitted to the wheel into which works a pinion fixed upon the crank-shaft of the steam-engine. When the head of water in the river or delivering drain does not vary much, it is sufficient to have one speed for the wheel; but where the tide rises in the river, it is desirable to have two speeds or powers of wheel-work, the one to be used at low water, the other more powerful combination to act against the rising tide. But in most cases it is not requisite to raise the water more than 3 or 4 feet higher than the surface of the land intended to be drained, and even this is only necessary when the rivers are full between their banks, from a continuance of wet weather or from upland floods.

In some instances the height of the water in the rivers being affected by the tide, the drainage by natural outfall can take place only during the ebb, and here, in case of long-continuing rains, the natural drainage requires the assistance of mechanical power.

It has been stated that the main drains have generally been made 7½ feet deep, or more in larger districts, so that the water may never rise higher than within 18 inches

or 2 feet of the surface of the ground, and the ladles or float-boards dip 5 feet below the water, leaving a foot in depth below the dip of the wheel, that the water may run freely to it, and to allow for the casual obstruction of weeds in the main drain, which, if it be sufficiently capacious and well-formed, will bring down the water to the engine with a descent of 3 inches in a mile.

Suppose then the wheel to dip 5 feet below the surface of the water in the main drain, and that the water in the river into which this water must be raised and discharged has its level 5 feet above that in the drain, the wheel in such case will be said to have 10 feet head and dip, and ought to be made 28 or 30 feet in diameter.

Mr. Glynn has found it practicable to throw out the water against a head of 10 feet with a dip of 5 feet, that is to say, 15 feet of head and dip, with a wheel of 35 feet in diameter, but in another engine more recently erected, he has made the wheel 40 feet in diameter. The engine that drives this wheel is of 80-horse power, and is situated on the Ten-mile Bank near Littlepool, in the Isle of Ely. The largest quantity of water delivered by one engine is from Deeping Fen, near Spalding; this fen contains 25,000 acres, and is drained by two engines, one of 80 and one of 60-horse power.

The 80-horse engine has a wheel of 28 feet in diameter, with float-boards or ladles measuring 5½ by 5 feet, and moving with a mean velocity of 6 feet per second; so that the section of the stream is 27½ feet, and the quantity discharged per second 165 cubic feet; equal to more than 4½ tons of water in a second, or about 16,200 tons of water in an hour.

It was in 1825 that these two engines were erected, and at that time the district was kept in a half-cultivated state by the help of 44 windmills, the land at times being wholly under water. It now grows excellent wheat, producing from four to six quarters to the acre. In many districts land has been purchased at from 10*l*. to 20*l*. an acre, by persons who foresaw the consequences of these improvements; they could now sell at from 50*l*. to 70*l*. an acre.

This increase in value has arisen, not only from the land being cleared from the injurious effects of the water upon it, but from the improved system of cultivation the farmers have been enabled to adopt.

The fen-lands in Cambridgeshire and great part of the neighbouring counties are formed of a rich black earth, consisting of decomposed vegetable matter, generally from 6 to 10 feet thick, although in some places much thicker, resting upon a bed of blue gault containing clay, lime, and sand.

When steam-drainage was first introduced, it was the practice to pare the land and burn it, then to sow rape-seed, and to feed sheep upon the green crop, after which wheat was sown. The wheat grown upon this land had a long weak straw, easily bent and broken, carrying ears of corn of small size, and having but a weak and uncertain hold by its root in the black soil.

Latterly however, chemistry having thrown greater light upon the operations of agriculture, it has been the practice to sink pits at regular distances through the black earth and to bring up the blue gault, which is spread upon the surface as manure. The straw by this means, taking up an additional quantity of silex, becomes firm, strong, and not so tall as formerly, carrying larger and heavier corn, and the mixture of clay gives a better hold to the root, rendering the crops less liable to be laid by the wind and rain, whilst the produce is most luxuriant and abundant.

On Investigations undertaken for the purpose of furnishing data for the Construction of Mr. Stephenson's *Tubular Bridges at Conway and Menai Straits. By* Professor E. Hodgkinson.

On a new Element of Mechanism. By Richard Roberts.

By this contrivance, a model of which was exhibited by Mr. Roberts, differential movements, for which more complicated mechanism is frequently employed, may be effected in a very simple manner.

The model consisted of a steel shaft, on which were fitted loosely two brass discs, each having a boss to keep it steady. One of the discs had on its circumference

eleven teeth, rounded at top and bottom, and was placed on the shaft: the other disc, which was plain, and rather the larger of the two, was on the excentric portion of the shaft, with its face to that of the toothed disc, and had four studs riveted into it at equal distances from each other, and at such a distance from its centre as to admit of their being brought successively, by the revolutions of the excentric, to the bottoms of the hollows in the toothed disc.

The following movements may be effected by this model:—

If the shaft be held stationary, and the discs be made to revolve upon it, the toothed disc will make twelve revolutions, whilst the other will make only eleven.

If the toothed disc be held whilst the shaft be made to revolve twelve times, the plain disc will revolve in the same direction one revolution only; and if the plain disc be held, the toothed disc will perform one revolution in the contrary direction for eleven revolutions of the shaft.

It will be evident that almost any other relative number of revolutions may be produced by employing one disc with a suitable number of teeth, and another with the smallest number of pins (not fewer than three), which will *not* divide the number of teeth in the other disc.

The idea of this novel element of mechanism was suggested to Mr. Roberts by "dial movement" in an American clock.

On Anastatic Printing and its various combinations.
By H. E. Strickland, *M.A.*

On the Ventilation of Collieries, with a description of a new Mine-Ventilator.
By William Price Struvé, *C.E.*

The ventilation of collieries is effected by means of large furnaces placed at the bottom of the upcast pits, the rarefaction produced by which causes the air to ascend the upcast pit, while a similar quantity descends the downcast pit. The great objection to this method is the variation produced by the neglect of furnace-men, and by the barometrical and thermometrical changes of the atmosphere, which, if accompanied by a sudden discharge of carburetted hydrogen gas from the goaf of a mine, is sufficient to produce extensive explosions. A large annual expenditure is also caused by the great destruction which arises from the gases and heat of the furnace to the flat chains, flat ropes, and cast-iron tubbing of an upcast-pit. It is proposed to remedy these evils by a new patented mine-ventilator of the following construction, which is calculated to take out of a mine an unlimited quantity of air. The whole upcast-pit is converted into an air-channel, connected with the ventilator by a culvert of the same size. The ventilator, which is worked by an engine of five horses' power, consists of two large air-chambers, resembling gasometers, moving up and down in water contained in a tank constructed of masonry; the chambers balance each other, and are surrounded with outside cases, so as to form double pumps; the inlet and outlet valves, when open, present for the ingress and egress of air the same amount of area as the upcast-pit; thus the only resistance to be overcome is that which arises from the slight friction of the parts of the apparatus and of the air in the passages of the mine. A ventilator on this principle is now (August 1848) being erected at the Eagles' Bush Colliery, calculated to pass through the mine forty thousand cubic feet of air per minute. The cost will be about £400.

On a new Low-pressure Atmospheric Railway.
By William Price Struvé, *C.E.*

The grand obstacles in the way of the working of existing atmospheric railways, are the difficulty of communicating the motion of the piston within the tube to the train without it, and the great leakage along the valve and around the piston. In the proposed plan these evils are to be thus remedied:—The railway is carried through a covered viaduct lighted through glass, the walls being constructed of masonry, and the roof of timber, or some other convenient material. The piston is a shield fixed on

wheels in front of the train, and is made to fit the interior surface of the passage as closely as is possible without actually touching it. The passage is exhausted by means of two large chambers, like gasometers, moved up and down in water by the action of a steam-engine. By the opening of valves in the shield, or of doors at the stations, the pressure may be diminished or entirely removed, and the train thus slackened or stopped without the necessity of stopping the engine. Each station being provided with a loop-line, in order that the continuity of the covered way may not be destroyed, the trains may be run into open sheds similar to those now in use for the purpose of receiving and taking out passengers.

As the rarefaction necessary to move the train is very small, a pressure of 0·6 lb. per square foot on a piston of nine feet square, amounting to nearly three tons, or nearly *four* times that obtained on the Croydon railway, little importance is to be attached to the leakage.

The advantages of the plan appear to be—increase of speed, safety and economy, absence of any resistance of the air in front of the train, and freedom from all risk of stoppage by snow-drift or frost.

The cost of the covered way and apparatus will not in ordinary cases exceed £7000 per mile, which is not more than the usual cost of locomotive engines, and of the extra weight of rails necessary for their support, nor than the cost of the present atmospheric railways.

A working model, twenty feet in length, with a covered way of six inches square, was exhibited to the Section.

On a new mechanical arrangement for communicating Signals and Working Breaks on Railways. By Wm. S. Ward.

Much attention has lately been paid to the contrivance of methods of communication between the engine-drivers of railway trains and the guards in charge of the carriages of the train, and of affording a means of communication between the passengers and the guards or engine-drivers; but no method has yet been suggested which has not met with objection.

It appears to the author that a simple mechanical contrivance for effecting a communication between the last carriage of the train and the engine, so as to ring a bell or communicate with a steam-whistle, affords the best means of attracting the attention of the driver and is the most likely to be generally useful.

It has occurred to Mr. Ward that the most perfect method of making communications on railway-trains is by the circular motion of rods extending under the carriages, so as to form a system of shafting which he calls torsion-rods. This he proposes to effect by means of rods moving in slides, and having springs attached, so as to extend the rods in like manner as the buffers of the carriages, each system of rods having a portion in the centre capable of revolving on bearings attached to the framework of the carriage or carriage-wheels, and connected by universal joints with the sliding portion of the rods, which revolves in and is supported by 'bushes' placed on springs, so as to give a little play both laterally and vertically. At each end of such system of rods is placed either a universal joint, capable of being attached to a similar joint, or a portion of a hollow cone, with a spike in the centre and teeth or claws on its outer edge, so that two carriages on which the rods are applied being coupled together, the cones on the adjacent system of rods are pushed together, and will be held in contact by the springs, and form a coupling-joint capable of communicating circular motion from one system of rods to another, so that such systems of rods will, when the carriages to which they are attached are coupled, form a continuous line of shafting. The torsion-rods will be extensible or compressible in length, and also yield laterally, according to the motion of the carriages, but will, when turned on their axes, communicate circular motion.

It is proposed to apply torsion-rods for communicating signals between guards and engine-drivers of railway-trains, affixing the rods under the carriages, so that systems of such rods forming a continuous shafting may give simultaneous motion to discs of wheels placed in the carriages, occupied by railway guards, and also to similar wheels placed upon the tender under the inspection of the driver; pulleys

being fixed upon the central portion of the shafting of the guard's carriages, and geared by elastic bands with corresponding pulleys in the carriages, suitably placed for being turned by the guard or engine-driver, and also observed by him if motion be communicated from any other part of the train, thus affording a means of communicating a limited number of useful signals.

Whatever may be the methods adopted of communicating signals on railway-trains, but little will be done towards the prevention of accidents, unless some more efficient mode of quickly stopping the train be also adopted.

When railway-trains seldom exceeded five or six carriages, and the maximum speed was about twenty-five miles per hour, it was found that the shutting off the steam and applying breaks on the tender were sufficient. Now when trains consist of ten to fifteen carriages travelling at the rate of fifty miles per hour, the breaks on the tender and those on the one carriage occupied by the guard are evidently insufficient.

The author, after stating objections to the system now in use, proposes his own views as follows:—It appears to me that the only means of ensuring the safety of railway-trains, and efficiently stopping them when required, is by increasing the number of breaks to be brought into operation at the same time. But to effect this with the appliances now used would require so considerable an addition of railway-guards, that companies prefer to run some risk rather than have an increased expenditure. I have therefore proposed the application of torsion-rods for communicating motion from one railway carriage to the adjoining carriages of the same train, so that the guard or breaksman may, in addition to working the breaks of the carriage on which he is riding, work the breaks on the adjoining carriages.

I believe the ordinary breaks may be efficiently put in action by the communicated circular motion; but in case the arrangement should be further extended beyond the power of the rods, I have devised other methods by which the breaks might be put in action by the application of a very slight force, but which I cannot very conveniently explain without better diagrams or models than it has been convenient to me to prepare here. By such arrangement the stoker or driver of a railway-train might work the break upon the tender as at present, and also the break on the first and second carriage of the train; or these might be supplied with self-acting breaks similar to those proposed by Mr. Stephenson, but so arranged that by a further application of my method of communicating motion by torsion-rods, they may be easily thrown out of gear; and the guard being, according to the most approved arrangement, placed at the last carriage of the train, in addition to working the break on his own carriage, will work the break on two adjoining carriages; thus an ordinary train will be supplied with six breaks instead of two, and without requiring any additional guard.

On the application of Gutta Percha to the Arts and Manufactures. By FRANCIS WHISHAW, *C.E., M. Inst. C.E.*

This communication, after detailing the general history of gutta percha, and its introduction into this country by Dr. Montgomerie, who received the gold medal of the Society of Arts, entered into full particulars with regard to the manufacture of this valuable substance in the shape of pipes, driving-bands, shoe-soles and heels, &c., and also gave the result of experiments as to its strength when mixed with various substances, and likewise of the effect of mixing gutta percha with various pigments.

The articles made of gutta percha which were laid before the Section to illustrate the communication, consisted of round and flat bands for driving machinery, pipes of various sizes, window-lines, thread, shoe-soles and heels, bowls, pump-buckets, fire-buckets, jugs, bottles, life-preservers, constables' staves, paper-weights, pen-trays, powder-flasks, bookbinding, curtain-rings, walking-sticks, whips, outside letters, surgical instruments, stereotype-plates, felt-edging, patent cloth, cricket and other balls, brackets, shields, medallions, coating for telegraphic wires, &c.

On the Patent Multitubular Pipes and Panergous Joints. *By* FRANCIS WHISHAW, *C.E., M. Inst. C.E.*

Multitubular pipes for insulating the wires of electric telegraphs are made of various kinds of clays and pounded pottery, and also of glass; they consist of any number of separate ducts formed out of the solid mass of clay; or if of glass, then several small tubes are placed within a larger tube, either of glass or pottery, and cemented together at the ends by means of plugs, of clay, glass, gutta percha, or other substance; the clay is pressed from a cylinder by mechanical means, through as many dies as there are ducts in the required pipe, a metal core being fixed in the centre of each die.

The panergous joint consists in forming a sinking or chase on the outside of one end of the pipe, and on the inside of the other end of the pipe, with two openings, one through the top and the other through the bottom of the faucet-pipe, through which either marine glue, asphaltum or other cement is placed, so as to form a perfect bond in the shape of a ring between one pipe and another: this renders the joint both air- and water-tight.

On the Subaqueous Rope for Telegraphic and other purposes. *By* FRANCIS WHISHAW, *C.E., M. Inst. C.E.*

A section of rope was exhibited, consisting of several small tubes of gutta percha enclosed within a larger tube of the same material, which latter is braided or served with white line of a thickness depending on the required length of the wires to be enclosed in the small tubes.

For hydraulic or pneumatic telegraphs the smaller tubes are dispensed with.

On the "Uniformity of Time" and other Telegraphs. *By* FRANCIS WHISHAW, *C.E., M. Inst. C.E.*

After describing the various modes of communicating signals by means of the semaphore and by electric telegraphs, Mr. Whishaw described the following of his inventions connected with the subject:—

1st. The Improved Hydraulic Telegraph.
2nd. The Hydro-Mechanical Telegraph.
3rd. The Telekoiograph, or Mechanical Telegraph.
4th. The "Uniformity of Time" Telegraph.
5th. The Telegraphic Code Box.
6th. The Telegraphic Despatch Box; and
7th. His new system of Two Letter-Codes.

The improvements in the hydraulic telegraph (1848) consist—1st, in the substitution of vertical copper wires attached to floats instead of columns of water, as in the original hydraulic telegraph (1838); 2nd, in using three-way-cocks instead of two separate cocks for the elevation and depression of the water at the different stations; 3rd, in the adoption of slides, whereby an infinite variety of codes can be used; and 4thly, in the addition of a time-piece.

The Hydro-mechanical Telegraph has the addition of rack, pinion and wheel-work, whereby the rectilinear motion is converted into a circular motion, the signals being placed on a dial, which dial is furnished with a hand or hands, which rotate in either direction, according to the elevation or depression of the water: moveable slides complete this arrangement.

The Telekoiograph, or Mechanical Telegraph, consists of a dial with one, two or more hands, moved by wheelwork, which hands point to signals arranged in circles on the dial. The action of working the machine is simply that of pulling a bell; the communication from one instrument to another is by means of wires and cranks; or it may be effected by different sounds communicated by electricity; moveable cards, or thin sheets of metal, forming complete colloquies on different subjects, are introduced in front of the dials, so that questions and answers and notices or orders are readily transmitted.

The "Uniformity of Time" Telegraph is on the principle of the centimetral hands of well-made clocks or chronometers, indicating to the hundredth part of a minute the same time.

In order to ensure this desideratum, the ordinary dial is surrounded by an annular compensating plate, either moved by hand or by a tangent screw arrangement, so that if two clocks differ as to time to the extent of any part of a minute, the centimetral hand will, by the movement of the annular plate, indicate precisely the same time at the two stations.

The subsequent arrangement, as to giving signals, is similar to that used in the telekoiograph as above described.

This telegraph is doubly useful, as it furnishes an accurate timepiece on one side and a colloquial telegraph on the other.

The Telegraphic Code Box, for public or private use, consists of a series of rollers placed within a mahogany box, the front of which is hung on hinges, and is inclined at an angle of 45°. In this front there are as many slits or openings as there are rollers within. At the top of each set of slits a letter is attached, and also another letter opposite the sets of slits laterally, so that by the intersection of two imaginary lines at any one of these openings the desired signal is found, as Ac, &c. The word or information intended to be communicated by the two-letter signal is written or printed on a slip of paper, and repeated many times; this slip of paper is wound round its corresponding roller, with its end projecting sufficiently beyond the slit or opening to afford hold for the thumb and finger to draw it out when the required word, &c. is cut off, and the same operation is repeated for the next signal.

The Telegraphic Despatch Box is intended as an accompaniment to every office where telegraphic despatch is required in the transaction of business. It contains not only everything that is required in the shape of stationery, postage-stamps, light-box, letter-balance, memorandum-slate, &c., but also the day of the week and month and the time of day. The whole is shut up (when not in use) by folding-doors, and forms a neat appendage to the library or office-table.

Two Letter-Codes. By the use of four distinct alphabets upwards of 100,000 changes are effected, either as words or sentences, and by varying the colour of these alphabets an infinity of changes may be produced. These codes extend to all words in the English language, including christian and surnames, names of places, ships, &c., and by their use the power of the telegraph is increased in a manifold ratio.

On the Improved Velocentimeter.
By Francis Whishaw, *C.E., M. Inst. C.E.*

The novelty and use of the first velocentimeter proposed by the author consisted, —1st, in the substitution of a central decimals' hand for that of the ordinary seconds' hand, whether placed centrally or excentrally, so that the time could be taken to the hundredth part of a minute; and 2nd, by surrounding the dial by an annular space containing velocities tabulated from 12·60 miles per hour up to seventy-five miles per hour, taking for a basis the fixed distance of a quarter of a mile.

In making a single observation on this plan, it was necessary to note down the decimal division at the time of passing the first standard, and also the decimal division at the time of passing the next standard, and having subtracted the one from the other, to look to the table for the result.

By the improved velocentimeter, which has the addition of a moveable annular plate, on which the table of velocities is engraved, instead of on the fixed dial, as by the first plan, a single experiment may be made by one observation: thus in passing the first quarter of a mile standard the central hand is made to coincide therewith, and also with zero (100) on the table; and when the next quarter of a mile standard is passed, the tabulated figures opposite to the central hand give the velocities required.

A Kilometral or any other British or foreign table may be substituted for the table of velocities when required, either for railway, steam-boats, or other experiments where time and distance are the principal elements.

On the Telekouphonon, or Speaking Telegraph. *By* FRANCIS WHISHAW, *C.E., M. Inst. C.E.*

The Telekouphonon is used in private establishments, warehouses, dock-yards, &c., for the purpose of holding a conversation between two persons at a distance from each other. It consists of gutta percha, caoutchouc, zinc, glass or earthenware piping, varying in diameter according to the required length of the pipe; terminal mouth-pieces of ivory, bone, hard wood, or metal, are securely attached to the pipes, having whistles, reeds, or other similar means of calling attention, in place of bells. When attention has been called, by blowing at the contrary end of the pipe, the whistle or reed is removed, and a conversation is readily carried on.

A compound terminal arrangement has also been introduced, having a mouthpiece, and also an acoustic duct connected therewith, so that a conversation may be carried on without moving the mouth until the communication is completed.

If the communication has to be transferred to a third party, an additional pipe is attached to the mouthpiece, and the sound being shut off from the *receiving*-pipe, is transmitted through the *sending*-pipe to the third party as above.

ADDENDA.

On the Boring of Mollusca into Rocks. *By* ALBANY HANCOCK.

On some Marine Animals from the Bristol Channel. *By* Prof. E. FORBES *and* ROBERT MACANDREW.

On Polystomella crispa *and the Classification of Foraminifera.* *By* W. C. WILLIAMSON, *F.G.S.*

Mr. Lennard exhibited Microscopical Drawings illustrating the Structure of Bone.

On the Boring of Sabellæ. *By the* Rev. J. BRADLEY.

On Additions to the Fauna of Ireland. *By* WILLIAM THOMPSON, *F.L.S.*

(See Annals of Natural History for this paper complete.)

Mr. J. Clark noticed the occurrence of *Colymbus arcticus* shot near Swansea.

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TO

REPORTS ON THE STATE OF SCIENCE.

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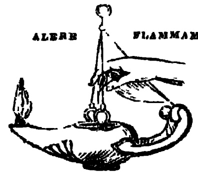
TO

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

THE END.

LONDON:

PRINTED BY RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.



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——	Part II. ...	1	0	6	1826.	Part I. ...	1	2	6	1842.	Part I. ...	0	16	0
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——	Part II. ...	1	2	6	——	Part II. ...	2	0	0					
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